THE

STUDENTS' ILLUSTRATED GUIDE

TO

Practical Draughting.

A SERIES OF PRACTICAL INSTRUCTIONS FOR

MACHINISTS, MECHANICS, APPRENTICES, AND STUDENTS AT ENGINEERING ESTABLISHMENTS AND TECHNICAL INSTITUTES.

BY

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PREFACE.

THE following instructions in practical draughting are written in such a way that they will be fully understood by apprentices and workmen. They may prove useful to many engineers, machinists, and mechanics, who think them worthy of an attentive perusal.

It would be superfluous to say much here concerning the importance of knowing how to draw, and the utility of draughting in constructive arts and industrial pursuits; but the fact cannot be too frequently reiterated that the education of the mechanic is incomplete without a thorough knowledge of mechanical drawing, and other branches inseparably connected with it. There are many fine inventions and improvements which have been lost to the public from the inventor's inability to express his ideas upon the drawing-board; and hundreds of machinists would be at this moment poring over their drawing-boards—inventing, scheming, and improving—had they studied and acquired a taste for practical draughting. In the workshop the practical part of a mechanic's business is to be learned. No one can claim to be a practical engineer and draughtsman whose practice did not commence in the workshop. This is the real studio for the mechanic. Here he can employ observation, thought and inquiry, make himself acquainted with the "mechanical powers," learn the nature of metals and the manipulation of the same; here he can acquire manual skill in working and fitting the different intricacies of steam engines, boilers, tools, and machinery generally. But be it remembered that the drawing-board and scientific book must go hand in hand with his practical experience. The mechanic should not only be able to work practically, but also to design practically; he should be able to express his designs, his improvements, and inventions, upon paper. The practical instructions here given will be in plain comprehensive terms, such as a teacher would use to his pupils, and it is to be hoped that they will serve, at least, as stepping-stones toward a thorough knowledge of the art.

In the present volume the author has devoted his attention to the practical rather than to the theoretical part of the subject. He has, therefore, omitted all reference to those problems of simple practical geometry which may be found in most school books relating to this subject.

PRACTICAL DRAUGHTING.

Instruments.

Students are very apt to consider a common set of instruments "good enough for a commencement," as they put it. Hence, without consultation, and without a knowledge of what drawing instruments are required, and ignorant of the essentials requisite to secure perfect accuracy in their operations, they unfortunately purchase instruments which are never found in the hands of good draughtsmen. The result invariably is general dissatisfaction, inasmuch as the instruments "won't work;" they will either cut the paper, or make a "ragged line," or not mark at all The points break off or get blunt. They are heavy, clumsy, and quite unsuitable for fine work.

Instruments in cases, sometimes *very nice cases*, can be bought for as low a sum as two or three dollars. The strongest inducement to purchase is the case. The instruments are almost useless, and few in number. Cases can be purchased from the sums named up to $200. But a good set of selected tools can be purchased for $25. To avoid ill temper, disappointment, and discouragement, cheap and inferior ones should never be procured.

If it takes six months to save money enough to buy instruments, wait that six months, but, in the meantime, let the

mind be fully made up to get, if only a limited number, the *very best drawing instruments* that can be obtained. Their operation and appearance will give great satisfaction. With care they will last a lifetime. The writer used a first-class lining-pen for twelve years, and then gave it to a friend as a valuable present. Therefore, in enumerating and describing instruments and drawing materials, reference will only be made to the best.

A machinist cannot do good or rapid work with dull, badly tempered tools, neither can the draughtsman produce fine, creditable drawings with dull, clumsy, badly-jointed and pointed, unadjusted, disproportioned drawing instruments. A few first-class instruments are infinitely more valuable than a great number of inferior ones. Explicitness on this subject is desirable. Beginners in the study of practical draughting may assure themselves that if there is any one time more than another when they need good instruments, it is when they commence to learn.

The following is a complete list of those instruments and drawing materials which are in common use by practical draughtsmen:

1. Drawing board. (Useful sizes 42 inches $\times$ 28 inches, and 32 inches $\times$ 23 inches).

2. T square with fixed and shifting head. (Useful size 42 inches long).

3. Triangles. One, 45°, 45° and 90°. One, 30°, 60° and 90°.

4. Irregular curves, batter slopes, and ellipses.

5. Drawing paper.

6. Thumb tacks and horn centers.

7. A small fine sponge.

8. A bottle of strong mucilage.

9. India rubber and ink eraser.

10. Lead pencils.

11. Small lead pencils for bows. (Hard, not soft).

12. Small smooth file on which to sharpen pencils.

13. Stick of India ink. (Good quality).

14. Set of cabinet saucers for ink and colors.

15. Camel hair water color brushes. (Sable hair are best).

16. Knife ink eraser.

17. Paper or wood scales and boxwood rule, 2 feet.

18. Tape line. (100 feet).

19. Steel squares, straight edges, outside and inside calipers.

20. Steel spring dividers with thumb screw.

21. Sketch books and sketch blocks.

22. Sheet-metal gauge, speed indicator, universal square.

23. A complete set of English, Swiss, French or German silver drawing instruments.

A set of drawing instruments, such as is usually regarded as complete, consists of the following parts.

Fig. 1.

Fig. 1. Proportional dividers.

Fig. 2. Large bows (6 inch pencil and ink).

Figs. 3, 4, 5, 6. Medium bows. (4½ or 3½ inch pencil and ink).

Fig. 7. Lining or drawing pens. (Two sizes, 4 and 5½ inch).

Fig. 8. Hairspring dividers. (6 inch).

Fig. 9. Spring dividers.

Fig. 10. Spring bow pen.

Fig. 11. Spring bow pencil.

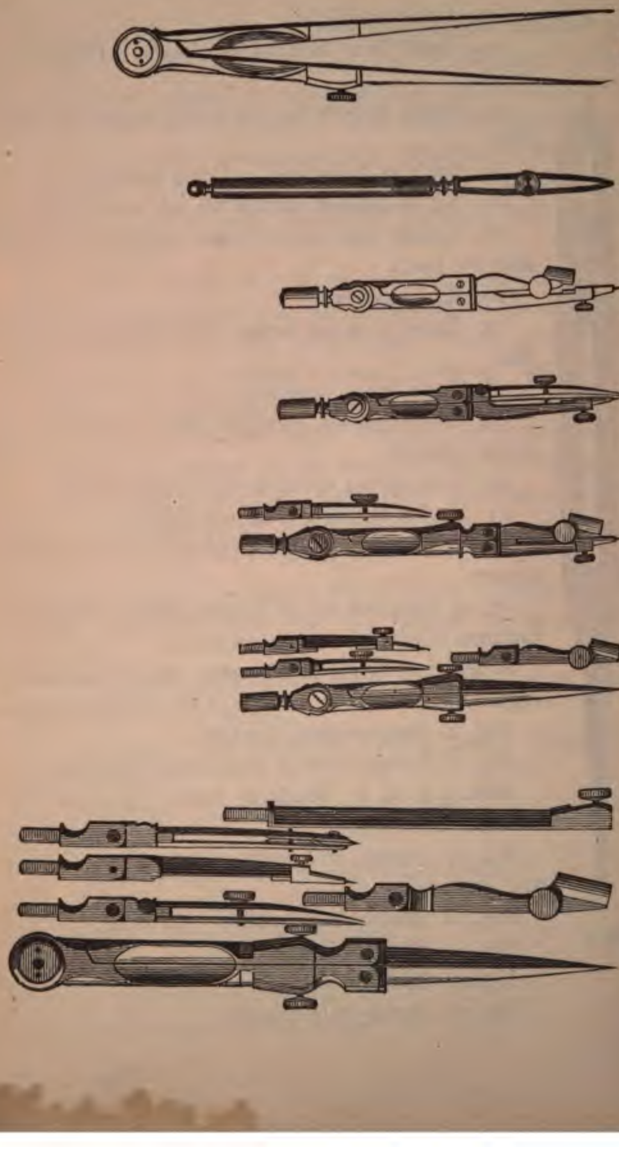


Fig. 2. Fig. 3. Fig. 4. Fig. 5. Fig. 6. Fig. 7. Fig. 8.

GERMAN SILVER DRAWING INSTRUMENTS.

Fig. 12. Beam compass.
Fig. 13. Metal protractor.

Fig. 9. Fig 10. Fig. 11

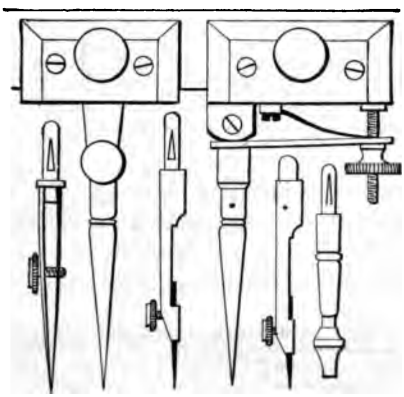


Fig 12.

Figs. 14 and 15. Plain flat ivory scale and protractor, 6 inches long.

Fig. 16. Flat ivory scale, 12 inches long.

The student may be surprised to find that so many articles are required by the practical draughtsman, but there is not a tool named that is not more or less needed, and at times in-

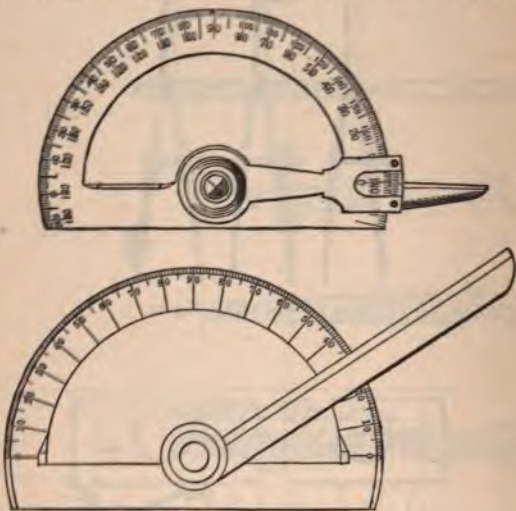


Fig. 13.

dispensable for measuring and drawing. We repeat, however, that a few first-class instruments are far more valuable (on account of their accuracy, durability and usefulness) than a large number of inferior and unreliable ones.

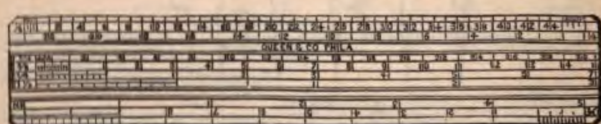


Fig. 16.

On reference to the catalogues of the principal dealers in drawing instruments and materials, it will be found that there

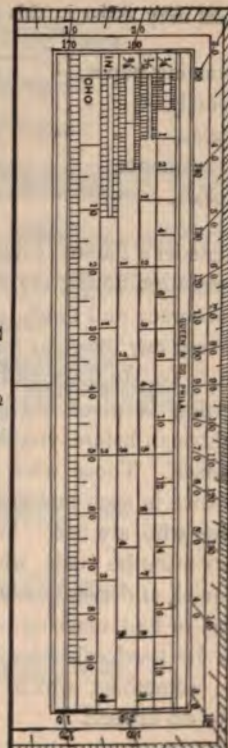


Fig. 14.

FRONT SIDE

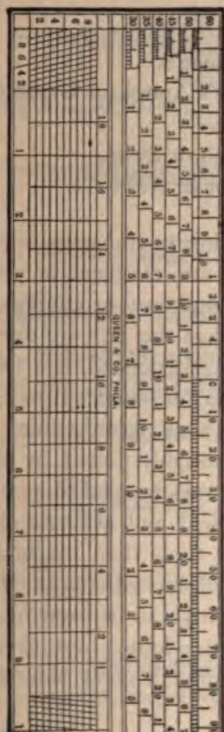


Fig. 15.

REVERSE SIDE

Paper.

The first thing to be considered in relation to a drawing board is its size. This is a matter in which students are apt to blunder; they think any convenient size will do, and order boards to be made to dimensions which suit their own fancy. When, however, they place a sheet of drawing paper on the board, they find considerable discrepancy in size and shape. Sometimes the sheet is too large; sometimes too small. Now, the white paper in sheets, purchased from dealers in artists' materials, is generally imported, and has certain sizes, thicknesses, and names. The sheets of different sizes are known by the following names:

Cap,	13 x 16	inches.
Demy,	20 x 15	"
Medium,	22 x 17	"
Royal,	24 x 19	"
Super Royal,	27 x 19	"
Imperial,	30 x 21	"
Elephant,	28 x 22	"
Columbier,	34 x 23	"
Atlas,	33 x 26	"
Theorem,	34 x 28	"
Double Elephant,	40 x 26	"
Antiquarian,	52 x 31	"
Emperor,	40 x 60	"
Uncle Sam,	48 x 120	"

Sheets, such as "Imperial" and "Double-Elephant," can be obtained of double thickness, although in the regular grade of drawing paper in sheets, it will be found that the smaller the sheet the thinner the paper, and, on the other hand, the larger the sheet the thicker the paper. Some of these sheets are "hot-pressed," others "cold-pressed." The former bear

a fine, smooth, glossy surface, and are suitable for fine line drawings; the latter have a rougher surface, and are more suitable for tinting and shading. The imported paper from England is mostly from J. Whatman's "Turkey Mill." It bears this stamp or water mark, which may be perceived when the sheet is held up to the light.

When this name can be read in the proper direction, or when the letters are right side up, the draughtsman may use that side of the paper as *the* side to draw on. Papers, white, brown and buff, can be obtained in rolls suitable for large drawings, and are used entensively for the rougher description of shop drawings and architectural details of buildings. For copying drawings there are "tracing paper" and "tracing cloth," or "vellum," as it is sometimes called. The former can be had in sheets or rolls; the latter in rolls. The tracing cloth is extensively used, on account of its durability and strength. It is invariably used in Patent Office business. Tracing *papers*, not cloth, can be had in sheets:

Demy, - - - - -	20 x 15	inches.
Columbier, - - - -	34 x 23	"
Double Elephant, - - -	40 x 26	"

Tracing cloth in rolls can be had of different widths up to 42 inches. Besides the papers mentioned, there are others used for special purposes, as "Muslin-backed Continuous Drawing Paper," "Double-length Profile Paper," "Continuous, or Rolled Profile Papers," "Cross Section Papers," etc.

Drawing-Board.

It will be seen that the size of a drawing-board should suit the size of drawing paper. Two sizes are very convenient—one to take "Imperial" paper, and the other for "Double

Elephant." The first should be 32 inches × 23 inches × 1 inch thick, the other 42 inches × 28 inches × 1 ¼ inches thick. These sizes allow the use of all sheets less than 40 inches × 26 inches. The smaller board is handier for smaller sizes of paper. There are various methods used in the construction of drawing-boards, the object being to have them "stand," and made so that they will not warp or crack. The boards must be of well-seasoned pine, thick, without knots, and cleated on the back. Hard wood is unsuitable, as it bends the points of the thumb tacks and instruments. The end cross-pieces, so frequently seen on thin drawing-boards, without any battens on the back, are objectionable on account of the unequal shrinkage, which causes projecting shoulders at joints and renders the edges unfit for the T square.

The accompanying figures represent good forms of drawing-boards. The right construction of such boards is generally obtained by entrusting the work to an experienced pattern maker. The left and bottom edges should be square with each other, and the corners left square or slightly rounded off. Knots, putty, and shellac, on the upper or drawing paper surface, should be avoided, especially if the paper is to be mounted or stretched by dampening and fastening it down with mucilage or glue.

Fig. 18.—PINE BOARD WITH HARD WOOD BATTENS.

Fig. 18 shows a board as ordinarily constructed with battens, and Fig. 19 represents the back of one of the best

forms of drawing-boards now made. It is made of pine wood, glued up to the required width, with the heart side of each piece of wood to the surface. A pair of hard wood battens are screwed to the back, the screws pass through the ledges in oblong slots, bushed with brass, which fits closely under the heads and yet allow the screws to move freely when drawn by the contraction of the board. To give the battens power to resist the tendency of the surface to warp, a series of grooves are sunk in, half the thickness of the board,

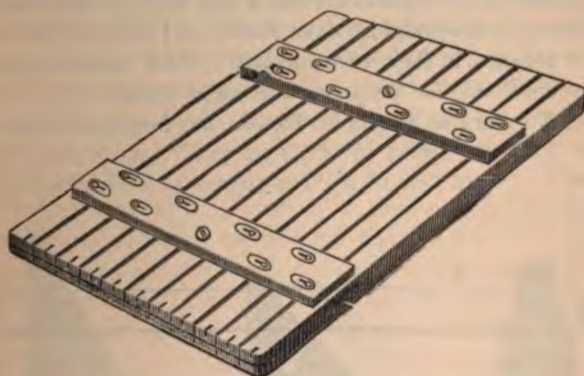


Fig. 19

over the entire back. These grooves take the transverse strength out of the wood to allow it to be controlled by the battens, leaving, at the same time, the longitudinal strength of the wood nearly unimpaired.

To make the two working edges perfectly smooth, allowing an easy movement with the square, a slip of hard wood is let into the end of the board. The slip is afterwards sawed apart at about every inch to allow for contraction.

T Square.

The T square is such an important instrument to the draughtsman, that too much pains cannot be taken to get one that is "true"—neither too heavy nor too light. There is no instrument which the draughtsman uses more frequently than this, and there is no drawing instrument that gets such a variety of experiments and fancy makes upon it as this. It is sometimes made of apple or pear wood, with a brass piece, about 1-32 inch in thickness, let in the edge of the "tongue," or "blade." Such squares are made and used by the French. Mahogany, rosewood, bird's-eye maple, and other of the finer woods are used in their construction. Black walnut is altogether unsuitable for T squares or straight edges.

The T square, as shown in Fig. 20, has four parts, known

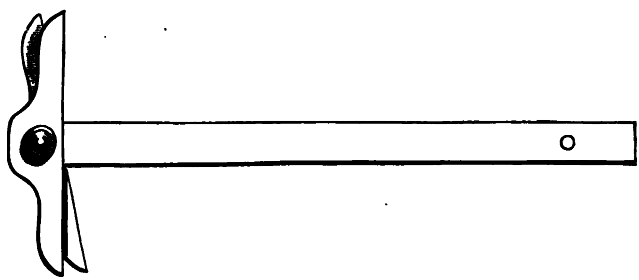


Fig. 20.

as the blade, the fixed head, the shifting head, and the swivel.

The head is held firmly by the left hand to the left edge of the drawing board, and the blade serves as a straight edge for horizontal lines that may extend the whole length of the paper. It can be used for either horizontal, or, by reversing to the bottom of the board, for vertical lines; and, by turning it over, so that that the shifting head is against the edge of

the drawing-board instead of the fixed head, lines at different angles may be drawn. A good proportion for a T square is to have the head one-third of the length of the blade. The length of the blade should be the length of the drawing-board; if it is shorter, inconvenience will be experienced when lines the whole length of the board are wanted.

Triangles.

Mechanical draughtsmen use, more especially, two triangles in connection with the T square, one having angles of 30°, 60° and 90°, and another having angles of 90°, 45° and 45°; also others, for making letters. These are of various sizes—from three or four inches and upwards. In use they are slid along the edge of the blade, and need not be any thicker than the blade. They are made of rubber or hard wood. Their shape is represented by Figs. 21 and 22.

Fig. 21.

Fig. 22.

Fig. 23.

By these, vertical lines, triangles, squares, and hexagonal, octagonal and twelve sided figures, diagonal section lines, etc., can be easily drawn, and, although the simplest, they are certainly among the most useful instruments used by draughtsmen. For ordinary purposes, the triangle with angles of 45° may be 4 inches long and the other 8 inches in length.

To see if the right angle of a triangle (90°) is correct, draw

straight line, and bring the edge of one of the sides exactly to it, having the right angle about the middle of it; then draw a line along the other side of the triangle from the right angle; now, it is to be supposed there is a right angle on each side of the last line drawn; to prove it, take up the triangle and place it in the same position it occupied before, but on the opposite side of the last line; now, if the angle of the triangle is not 90°, when one side corresponds with its line the other will not. To prove the angle of 30°, see if it is one-third of ninety, and the angle of 60° should be double the 30° angle.

The edges of the triangle can be tested in the same manner as the edges of a straight edge. The simplest way to test the right angle of a triangle, is by the right angle of the T square, one edge of the triangle being held against the blade and the two right angles brought together; the other side of the

Fig. 24.

triangle should fit evenly on the head of the T square other plan is the most correct, as there may be an error *angle of the* **T** square.

"Batter slopes" made of hard rubber, as illustrated by Fig. 23, are useful in giving batters of walls and rock, and are used in a similar way to the triangles. Fig. 24 shows a template specially intended for forming letters.

Irregular Curves.

Irregular curves, or, as they are sometimes termed, sweeps, as represented by Fig. 25, are used for curves that cannot be put in by the bows. They are very useful when elliptical or parabolic curves are desired, in preference to circles or arcs of a circle. They are much used in design and architectural drawing. They are made of thin hard wood or rubber, and sometimes of horn.

Drawing Scales.

One of the great advantages resulting from a knowledge of practical draughting is, that it enables a mechanic to *read* a drawing when given him as a guide for his work. On the other hand, if a mechanic has not a knowledge of scales, and the drawings are not figured, he will find it a difficult task to work exactly to the designer's plans. It is a practice which is getting every day more general among draughtsmen, to figure exactly and minutely every part of their drawings which are drawn to a scale. Even in full-size drawings this system of figuring is not objectionable. It is a system which should be followed whenever a drawing is made "to work to," for it allows the workman to comprehend at a glance the size of his work and the pieces he has to get made. Figuring makes a drawing comprehensible even to those who cannot make drawings. It obviates the necessity of having the mechanic to measure with his rule (too often a very dirty and greasy one) the dimensions on the drawing. Still further, it allows

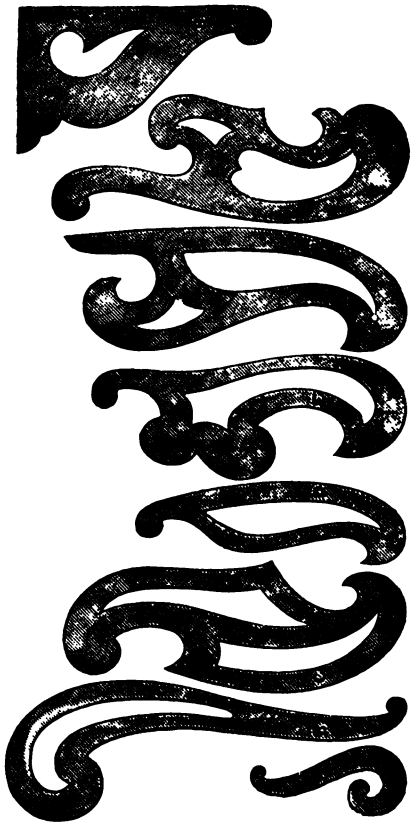


Fig. 25.

the draughtsman to make an alteration in the size of any part by simply altering the written figure and not erasing the lines. Lastly, it adds to the correctness of the drawing—which, being on paper and affected slightly by the weather—all inaccuracies will be covered by the plain written dimension, as 48 inches long, or 36 inches diameter; or 6 inches $\times$ 4 inches $\times$ 4 inches, etc. Drawings are almost generally made "finished size," that is, the dimensions are for the work when it is completed. Consequently all the figures written on the different parts indicate the exact size of the work when finished, without any regard to the size of the drawing itself, which may be made to any reduced and convenient scale. Drawings can be made full size, but to make them so is often inconvenient and sometimes impossible. Recourse must be had to a scale when all the parts can be delineated in proportion with as much accuracy and ease as in full-size drawings. Work of every description, and plans of buildings, machinery, or mechanical apparatus, can be drawn to any of the following scales:—Half size, 6 inches = 1 foot; third size, 4 inches = 1 foot; fourth size, 3 inches = 1 foot; fifth size, 2·4 inches = 1 foot; sixth size, 2 inches = 1 foot; eighth size, 1½ inches = 1 foot; tenth size, 1·2 inches = 1 foot; twelfth size, 1 inch = 1 foot; sixteenth size, ¾ inch = 1 foot; twenty-fourth size, ½ inch = 1 foot; forty-eighth size, ¼ inch = 1 foot; ninety-sixth size, ⅛ inch = 1 foot; one hundred and ninety-second size, or 1-16 inch = 1 foot.

In addition to these scales there are intermediate ones, such as 7-16 inch, 5-16 inch, 3-32 inch, in short, any length may be set off to represent twelve inches or one foot, and this foot subdivided into twelfths or inches. In practice the scales that are mostly employed are those which are to be found on the ordinary two-feet rule. These are half size, one-fourth size

one-eighth size, one-twelfth and one-sixteenth size. These scales are easily understood and read by the workman, as being found on his standard of measurement. The best scales to work with are one-eighth and one-fourth size, viz., 1½ inches = 1 foot, and 3 inches = 1 foot. These scales are those usually adopted when the size and description of the work will allow.

There are a great many persons who cannot fully understand how to use these scales. Here, then, are some very explicit instructions. "Take off" on the compasses three inches and make a line on paper exactly this length. This is now the measurement for one foot. If any part of the work is to measure 12 inches, then it must be drawn as 3 inches. Again, if inches of this foot are wanted: divide the three inches into twelve parts, and consequently every twelfth part will represent 1 inch of the scale; these subdivided again will represent half inches. Now the reader will please observe that these divisions are already to his hand, and divided off for him on the ordinary two-feet rule. Inasmuch as 3 inches = 1 foot, then ¼ inch = 1 inch; ⅛ inch = ½ inch; 1-16 inch = ¼ inch; 1-32 inch = ⅛ inch; 1-64 inch = 1-16 inch; and similarly with one-eighth size or 1½ inches = 1 foot, for 1½ inches contain just twelve-eighths, which of course serve as inches, sixteenths as half inches, and thirty-seconds as quarter inches. The dimensions of the several parts of a drawing are frequently the result of arithmetical calculation; and for such drawings a decimal scale with tenths and twentieths must be used.

Diagonal Scales.

A "diagonal scale," giving the fractional parts of an inch in *twelfths*, can be constructed as follows: Draw seven

horizontal parallel lines, and divide these by perpendicular lines into any number of equal spaces which may represent feet. From the middle point of the first division of the top line, draw the diagonal lines, which will intersect all the horizontal lines. Number the points of intersection, as 1, 2, 3, etc.; and also the perpendicular lines, 1, 2, 3, etc.; beginning on the third perpendicular line to the right; the scale is then complete. This manner of making a scale is illustrated by Fig. 26. Its dimensions, as here given, are 2

Fig. 26.

inches × ½ inch, but of course these can be enlarged and changed at pleasure. Referring to the diagram, it will be seen that the divisions made by the perpendicular lines 1, 2, 3, will stand for feet, and the divisions made by the diagonal lines will be twelfths of one foot or inches. One foot and one inch (figured on drawings 1′ — 1″) would be measured on the second horizontal line (counting from the bottom) from perpendicular line 1 to first intersection 1. Again, three feet and six inches (3′ — 6″) would be measured from the extremity of the top line to the centre of the first division containing the diagonal lines. In using a scale constructed in this manner, the dividers are required; and, therefore, it is not convenient for general use.

Referring back to Fig. 15, which shows the reverse side of a plain, flat ivory or boxwood scale, found in many cases of drawing instruments, it will be observed that two of these diagonal scales are given, and that the divisions are ten and not twelve in number. An enlarged view of this scale,

termed a decimal scale, is shown in Fig. 27. The "decimal diagonal scale" is constructed in a similar way to the former one, viz.: by the intersection of diagonal and horizontal lines. The diagram exhibits a decimal scale of one inch to the foot.

Draw eleven equidistant and parallel lines, forming ten spaces, and perpendicular lines for the foot divisions. Divide the first division into ten equal parts at the top and bottom lines, and draw the diagonal lines, 0, 1, 2, 3, 4, etc. By this

Fig. 27.

means the unit of measure is divided into 100 equal parts. Example:—If 1 foot and 5-10 (written 12·5) were required, the points of the dividers would be placed on 1 and 5 on the top line. Again, if 12·8 inches were required, the points would be extended from 1 to the 8th diagonal. In like manner, for 12·4 inches, the dividers would embrace the top horizontal line and 4 diagonal; for 12·41 inches, the *second* horizontal line and 4 diagonal; for 12·42 inches, the *third* horizontal line and 4 diagonal; 12·43 inches, the *fourth* horizontal line and 4 diagonal; for ·5 inches, the top horizontal line, from 0 to 5 diagonal, etc. The student will note that the fractional parts are measured entirely on the *diagonal* part of the scale; the 12 inches (or one foot) being the unit of measure. On this same plain ivory scale will be found small simple scales (see representation of the "front side") 1/ inch, ¾ inch, 1 inch for feet and inches.

The scales explained here besides others appearing on the same instrument are now seldom used.

Paper and boxwood scales with tenths and twelfths are easily procured, and the divisions being brought to the edge, they are undoubtedly the best and most useful ones.

Ink.

India ink has been named "the draughtsman's color." Certainly, to the mechanical eye, a well-lined or finely-shaded drawing of machinery has great attractions. Formerly, when photography was in its infancy, the expert draughtsman was frequently required to produce pictures of machinery that were lined out to a scale, and then shaded up and tinted by means of brushes and colors. Some such very beautiful pictures of beam and horizontal engines, locomotives and pumps are yet to be seen, although they were executed years ago by draughtsmen who spent many days in their execution. These pictures can be ranked with the finest oil or water-color landscapes; they exhibit accurate study of light and shade, and a finish that resembles the most elegant photography.

Such pictures are the draughtsman's highest art; the artistic eye, the steady hand, besides the closest and most patient application are all required for their production.

If the quality of India ink should be good for line drawings, it certainly must be of the finest when used for shading with the brush. As generally used now, it is procured in sticks and rubbed down in a circular cabinet saucer or oblong slab. Fig. 28 represents the form of Winsor & Newton's best India ink. Fig. 29 represents a "nest of cabinet saucers," which allow different tints and colors to be mixed for use at one time, one saucer acts as a cover to the other—keeps dust out and prevents rapid evaporation.

Fig. 30 shows a patent covered ink slab in which the ink

or rubbed on an inclined plane and the ink allowed to flow into a small circular basin, from which it is dipped up by the ruling and bow pens. For line drawings ink should be jet black. Common writing inks are not used for architectural and mechanical drawings. Liquid India ink, that is, ink

Fig. 29.

Fig. 28.

Fig. 30.

already mixed for use, can now be procured in small bottles, and there is now in the market a really fine article to be had in this form, which is a handy one and liked by most draughtsmen.

Fig. 31.

Fig. 32

Fig. 33.

Colors.

The colors required by mechanical draughtsmen are few in number, but should be of the best quality. Besides India ink the following water-colors are required:

1.—Neutral tint.
2.—Prussian blue.
3.—Chrome yellow.
4.—Gamboge.
5.—Raw sienna.
6.—Carmine.
7.—Vermillion.
8.—Venetian red.
9.—Sepia.
10.—Indigo.

These water colors come in hand cakes. Fig. 31 represents a whole cake, and Fig. 32 a half cake. Winsor & Newton are among the most celebrated manufacturers of water colors.

Certain colors and tints represent different metals and materials. With the exeeption of Prussian blue for wrought iron and steel, there are no colors which can be properly termed technical or conventional colors. Every draughtsman has his favorite mixtures or tints, and a colored representation of cast iron in Washington, D. C., may be a very different tint to that used by a draughtsman in London or Paris. For instance: India ink, Prussian blue and a little crimson lake will, if mixed in proper proportions, give a good gray for unfinished iron castings.

Neutral tint by itself is used for the same purpose; also India ink and indigo. Curved surfaces of finished or polished cast iron are, in a shaded drawing, left white; plane surfaces are faintly tinted with indigo. Wrought iron is indicated by

light Prussian blue. Steel by a darker shade of Prussian blue. Brass can be represented by chrome yellow, or a combination of gamboge and crimson lake. Copper, brick, stone, wood, leather, and other materials are represented by colors which resemble theirs. Imitations of oak, pitch pine, and walnut, for instance, can be given by representing the grain and color of those woods. Camel hair brushes, as represented by Fig. 33, are suitable for ordinary coloring. Sable hair brushes are more elastic, and more expensive, and should be reserved for the finest work. The former are termed "Double Camel Hair Wash Pencils." They have metal, not quill tubes.

The tubes holding the brushes are permanently secured to the handle. One brush is used to hold color and the other to hold water. As the points of the brush are what are worked with, the points should be fine ones, as shown in Fig.

How to Mount Paper.

Drawing paper can be fastened to a board either by means of "thumb tacks," as represented, Fig. 35, or by dampening the sheet, and while it is moist, gumming the edges to the board. This is termed "mounting" the sheet, and as to do

Fig. 34.

Fig. 35.

it well requires some knack, and as it is an operation in which students frequently fail, a minute explanation of what to do and how to do it is here given. One word, first, about thumb-tacks. In selecting them, get those in which the steel point is *screwed*, not riveted into the head. The head should

be convex and thin, so that the blade of the T square will slide over it without striking and notching its edge. Thumb-tacks with raised edge are very objectionable on account of the blade of the square coming into contact or striking against them. Horn centres, Fig. 34, are useful where a number of arcs or circles are to be drawn from one centre; they prevent large unseemly holes in the paper. In place of a horn centre, a small piece of card board gummed to the paper may be substituted, but horn is better.

When drawings for the workshop are "wanted right away," as they generally are, or when a drawing will not require much time to make it, the paper may be held down by thumb-tacks, but when a drawing will occupy much time in execution, owing to alterations in design and minute details, and when tinting and shading in India ink and water-colors are to be applied, the sheet should always be mounted. The way to do this is as follows:—The drawing-board and T square being, of course, "true," and in good condition, the sheet of paper is first laid on the board *right side up*, its edges as near parallel with the board edges as possible. Take the T square and rule off half an inch from each edge; cut off with a sharp knife the strips ruled off. The object of doing this is to get rid of ragged edges, and to have the edges of the paper parallel with the edges of the drawing-board. It may not be always necessary to do this, but in every case there should be no uneven edges, and it is best to have the edges of paper and board parallel with each other. Turn the paper over, and with a small fine sponge and clean water dampen well the whole surface, except half an inch or a little more at the sides, if the sheet is "Double Elephant" or larger than that size. See that every part of the sheet is well moistened except the edges or border, which are left dry to take the gum or glue. Now, with a mucilage brush well

charged with strong mucilage, paint the dry edges. Go round these edges with the brush until it begins to feel sticky in the hand. Then taking the two upper corners of the sheet in the forefingers and thumbs, hold it up perpendicularly. Square the sheet with the board, and lay down the sheet, being careful not to let the gummed edges touch the board anywhere but just where it is to adhere.

With the thumb nail (*if it is quite clean*), or a smooth ivory handle, rub down the edges until they stick evenly to the board without any over-laps or puckerings. The sheet will now appear raised and uneven, and blistered. Leave it alone; don't touch it with the hands or anything else. It will soon be discovered that a dampened sheet of white paper is very sensitive to dirt or the slightest impress. Place the board flatwise (not edgewise) in a cool place to dry, and in a short time the paper will have contracted and dried, presenting a beautiful smooth surface, which is permanent. The success of this operation depends in a great measure upon the consistency of the mucilage. An ounce or two of gum arabic, procured from an apothecary, completely dissolved by water in a mucilage or wide-mouthed bottle, gives an aqueous solution of gum stronger than ordinary mucilage. The object is to get strong, not thin gum—gum that will *dry quickly* and *hold firmly*. Thin glue can be used, but as it dries quickly each edge of the paper must be folded down as soon as glued. With large sheets of roll paper glue is preferable to gum, on account of the great amount of contraction.

Paper is sensitive to the condition of the atmosphere. When it is pinned down, or even mounted, it will often show expansion, and in this case must be re-pinned or dried, so that the lines, if any are drawn, shall coincide with the blade of the T square as originally drawn.

The great desideratum in putting a sheet of paper on a

drawing-board is to have it smooth and even. Sometimes it will be found necessary to trim off the edges. Drawing paper procured in sheets, should be kept flat in a drawer and not rolled. Never roll a sheet of paper or drawing when it can be preserved flat, and finger them as little as possible. Do not make a drawing-board, when in use, a shelf to hold instruments, cabinet saucers, rule, etc. These, with other tools, should be placed at the right of the board, but not on it. Practice will soon convince the young draughtsman of the correctness of these instructions.

Management and Care of Instruments.

When using drawing instruments be careful in learning how to handle them properly. The proper way is the easiest one. Beginners, and especially those who are accustomed to use iron compasses and steel dividers in workshops, are very apt to employ both hands in opening and closing the dividers and bows. This looks very awkward and is so. The T square belongs to the left side of the drawing-board, and is operated by the left hand. The right hand should be kept free for the purpose of picking up pencil, pen, and bows; adjusting and marking off. The left hand controls the T square and the triangle that slides along the upper edge of the square; the right hand is for the instruments. The joints of the instruments must be neither too loose nor too tight. They should open and close on a moderate pressure from the thumb and fingers. Practice will regulate this. A small, delicate hand can work with slacker joints than a heavy one used to hammer and file.

Be particular in having the legs of the dividers exactly the same length, and sharp, so that in pricking off distances, and dimensions, and centres, the indent or hole made in the paper is as small as possible. One of the beauties of a fine drawing

is that the compass point marks can scarcely be discerned. Hence the touch must be light, and the prick point made by the dividers and needle points should be no more than can be just seen. Again, if the compass-point holes are large, the ink will flow into them when inking in, and the appearance of the lines marred. To avoid making a great many compass-point holes, the student should accustom himself to the use of a flat scale. Paper scales are the best. By these he is enabled to dot off dimensions with his fine pointed pencil. This method of dotting off from the division lines on the edge of a scale has become a very general practice, and is a good one, as time is saved, accuracy insured, and holes in the paper avoided.

When using the bows see to it that the steel-pointed leg that is put down first on the paper, to secure a centre for a curve or a circle, is a trifle longer than the pencil or pen leg. If this is not the case the pencil or pen may touch the paper first and then a provoking slip will follow. Another thing should be remembered, viz., always have the steel-pointed leg of the bows as near perpendicular to the paper as possible, in order that the point may not work out a large conical hole, which it will do if the centre is much used, and the leg stands at an angle to it. Here are a number of memoranda in brief:

Avoid fingering your drawing sheet as much as possible. In pointing to any part of the drawing use a pencil and *not your finger* as a pointer. If foremen and master-mechanics would remember this, they would save some annoyance to draughtsmen, as sweaty, and greasy and dirty fingers leave indelible marks. Avoid rubbing out and constantly cleaning with India rubber as much as possible. Much rubbing destroys the surface of the paper. If you make wrong lines or wish to make alterations, the part to be altered should be rubbed out entirely and completely. Do not trust to memory

to make the change when you ink in; your attention then is pretty well absorbed in making nice lines.

Some draughtsmen put a round, sharp point on their pencils in preference to a flat one. A round point is better for dotting off from the divisions on scales, but a flat point that can be kept close to the edge of the square or straight edge will not require sharpening so often as a round one. In all cases the cedar should be well cut away. A small, smooth flat file should be used to sharpen lead pencils. The pencil should be rubbed on the file, not the file on the pencil.

In rubbing out a pencil line, rub out in the direction the line is drawn. Before putting away instruments, clean the ink well out and wipe them over with a piece of chamois leather. The perspiration from the fingers tends to discolor and rust them.

How to Commence.

It is presumed that by attention to the instructions already given the student has made himself acquainted with the names and usage of drawing instruments, and that now he is desirous of beginning to draw. The first exercises and practice should consist in learning to sketch and trace. First learn how to sketch. Furnished with a strongly-bound manuscript book, having lines ruled like letter paper, or having blue lines ruled both ways, parallel with the top and side edges, thus presenting a number of squares about 3/8 inch or 1/8 inch in size; a lead pencil of medium hardness, or a stylographic or common pen, a pair of outside and inside calipers, a steel square, a four-jointed two feet rule, and a wooden measuring stick of suitable length—the young draughtsman is prepared to sketch any and everything that has length, breadth and thickness in the constructive arts. Look about, and there are

an infinite number of objects for studies—furniture, hardware, stoves, carriages, locomotives, boats, machinery, buildings, etc., etc. These can all be outlined in the sketch-book by pen or pencil. Here are some important but simple instructions: Learn to sketch intelligibly so that other parties who even don't understand drawing can comprehend your sketches—don't forget to understand them yourself. Remember the simple fact, that edges of plane surfaces are lines, and that when you put down a line it represents the edge or outside of something. Pay especial attention then to outlines. Don't endeavor to be artistic before you are mechanical. At present you have little to do with shading, shadows, tinting and effects. Sketching is not as easy as you may imagine. Some persons have a talent for sketching quickly and in proportion. Learn to be accurate before you are quick or rapid; if you can get to be both, so much more in your favor. About the worst thing is to be slow and inaccurate. What shall you begin to sketch? Sit down in front of the fireplace in your parlor or bedroom, and sketch the mantel piece, or sketch a window, a drawer, or a table. You will find that horizontal and vertical lines and a few curves will represent these. Then when you have lined them take your rule and calipers and measure heights, lengths, breadths and diameters. Write these dimensions in neat, plain figures.

Another note is necessary just here: You have, at present, nothing to do with perspective. Workmen and any other parties can frequently get a good general idea of a building or machine from a drawing in perspective, but men cannot measure or work from perspective drawings. Therefore, in sketching, draw just as the object looks when directly opposite, squarely before you. You are not supposed to look sideways, or at any convenient angle, but in the direction of straight horizontal and vertical lines from the eye. Hence we

get names of views technically and familiarly known as front elevation, side elevation, end elevation, back elevation, plan, general plan. If lines are to appear on the sketch to indicate parts hidden, or parts which are not seen, when looking as already explained, they must be dotted, and sections—parts cut open, so to speak, and then looked at, must be indicated by a number of equidistant parallel lines drawn at an angle of 45°.

These instructions will be clearly understood by future illustrations. Let your sketch-book be your constant companion. There is a broken paddle or propeller shaft on the wharf or at the dock; go and sketch it and measure it; length and diameter of journals, from centre to centre of journals, etc. Sketch the fracture just as it looks. Sketch the whole in such a way that you can make a drawing by which a new similar shaft could be made at a forge five hundred miles away—a drawing to a scale that requires no questions, but tells its own story intelligibly and comprehensively. If the object you are sketching is above you, like, say shafting, or below you as the base of a column, the parts must be sketched just as they would appear if on a level with your eyes.

The sketch book may be filled with outlines of machine or other work, in short, of anything that the draughtsman may wish to preserve for finished drawings or reference. For instance, he may see a bookcase in a friend's house that is attractive for its good proportions and convenience, or, during some trip, he may see some neat summer house, a conservatory, a boat, or, still again, he may be pleased with the design and proportions of some monument, or ornamental work in wood or stone—these, and such as these, he can sketch and measure, and enter the particulars in his sketch book. From se sketches he is enabled to make drawings to a scale and

possibly improve upon the design. At any rate, they are valuable for reference as aids to originating new designs. Whether the aim is to become a professional draughtsman in an engineer's or architect's office, or to become proficient as an amateur in free hand and geometrical drawing, the art of sketching and measuring should receive close and constant attention. By daily practice the student will be educating both hand and eye, and he will find it a fascinating, a useful, and pleasant employment. Besides, he will gather a stock of knowledge and information that will surprise him in its accumulation and its retention in the memory. To draw lines approximately straight and circular is not difficult of attainment.

Blackboard Drawing.

But besides the sketch book, there is another exercise which should receive attention, and that is drawing on the blackboard. The use of the blackboard for instruction in all subjects of drawing is highly essential. It is now to be found in all academical institutions, in the lecture room, as well as the school room. No draughting office is complete without one; and if the lecturer and teacher find it so invaluable as a means of conveying instruction in a great number of scientific subjects, why should not superintendents, master machinists, and foremen use it more generally and frequently than they do in explaining their ideas and "getting out work" for their draughtsmen and workmen? Many a man can chalk out on a blackboard, or a piece of sheet-iron, or on the floor, just what he wants to show, or "to see how it looks full size," but cannot explain verbally, who would make sorry work with pencil and paper. We advocate, therefore, a large blackboard in every draughting office, in every pattern, machine and

clear view. If it be necessary that lines be made both above and below these points, the position of the body and head must be raised or lowered, so as to avoid stooping or straining, which is fatal to good work. Drawing on the blackboard is the most perfect illustration of the expression "free-hand drawing." Practice in this free-hand sketching in the sketch book and on the blackboard should alternate with geometrical drawing, of which we will give some illustrations further on.

Study of Geometry.

There is a language in drawing, and that is geometrical language. We speak of surfaces, lines, angles, triangles, squares, pentagons, hexagons, etc., and machinists, carpenters and builders, in common with all mechanics, perform their work on geometrical principles, and by means of geometrical figures. The mechanical engineer could not succeed without them; and to the military man, the navigator, and the civil engineer, they are the foundation of all their operations. In short, in every human pursuit, geometrical principles will be found. It will always be so. Man at best is but a copyist, for the beautiful in art is taken from the works of nature, as found in the animal, vegetable and mineral kingdoms. The *elliptical* green leaf, *hexagonal* cell of the bee, the *spherical* and *conical* forms of fruits and vegetables, and the *cubic* crystals of the mineral kingdom, are proofs that "God Himself geometrizes," and we in our mechanical, agricultural, and domestic pursuits are ever striving for and copying all that is beautiful and geometrically correct.

The importance of a knowledge of geometrical drawing at the commencement of a study of a drawing is paramount; as well might a student in music expect to become a player of 'ugues, or Handel's oratorios, without learning the

rudiments of that science, as a draughtsman to become expert in his art without a knowledge of practical geometry. Says Walter Smith, State Director of Art Education in Massachusetts, "I have never known a case where a student did not progress more satisfactorily in his studies after a course of practical geometry." It would be superfluous, however, to introduce a description of the numerous geometrical figures

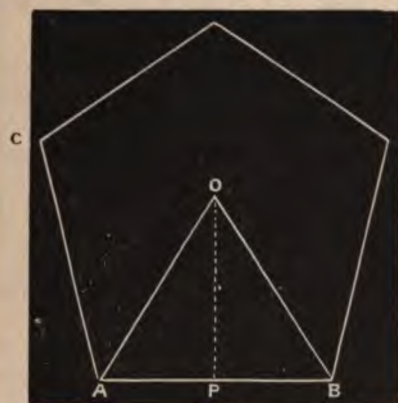


Fig. 36.

here. What references we now make to them will only show students that before they can understand and *apply* them to construction drawings properly, they must get posted from the elementary works on the subject. The student will find that the figures enumerated below constantly occur in mechanical and architectural drawings, as, for instance, in the case of square and oblong plates, slabs, panels, hexagonal nuts and bolt-heads, octagonal boxes, shafts, columns, etc.; these can all be drawn geometrically in a quick and accurate manner. In the delineation of hexagonal and octagonal figures, the two set-squares or draughtsman's triangles, already described, become

useful, since their angles are the suitable ones for those figures.

The following table gives the circumferential and central angles of ten regular polygons:

Name of Polygon.	No of Sides.	Polygon Angle.	Central Angle.
Triangle	3	60°	120°
Square	4	90°	90°
Pentagon	5	108°	72°
Hexagon	6	120°	60°
Heptagon	7	128° 17′	51° 43′
Octagon	8	135°	45°
Nonagon	9	140°	40°
Decagon	10	144°	36°
Undecagon	11	147° 47′	32° 13′
Dodecagon	12	150°	30°

In Figure 36 the angle A O B is called the central angle, and the angle C A B the polygon angle.

Name.	No. of Sides.	Angle O B P.
Trigon	3	30°
Tetragon	4	45°
Pentagon	5	54°
Hexagon	6	60°
Heptagon	7	64° 2-7
Octagon	8	67° 1-2
Nonagon	9	70°
Decagon	10	72°
Undecagon	11	73° 7-11
Dodecagon	12	75°

The measure of an angle is an arc of any circle contained between the two lines which form that angle, the angular

point being the centre; and it is estimated by the number of degrees contained in that arc.

We have already alluded to sketching and drawing on the blackboards as among the best elementary exercises for students. Next in order we commend the exercise of describing regular polygons, the study of decimal fractions, and mensuration. We repeat: To give descriptions and explanations of studies in these branches here would be only to rewrite what has been and is being repeatedly published in school arithmetics, and in nearly all engineers' and mechanics' guides and hand-books, but we wish to impress upon the student that the sooner he supplies himself with some of these valuable aids, and makes himself master of the contents, the sooner and better he will be enabled to draw quickly and satisfactorily to himself and others.

The Circle.

One of the most important geometrical figures is a circle. There is much to be said about it. We have selected it as a single illustration for two reasons. First, to show the student how much there is to learn in the study of *one*, apparently, simple figure. Second, to show how necessary it is for a draughtsman to have, at least, *some* knowledge of practical geometry and mensuration.

Before you read any further, note the numerous objects or parts of objects about you, and *in the distance*, that have an entire, or partially circular form, the outline of which you would represent on paper by a circle or arcs of a circle, as tables, clocks, chairs, brackets, wheels, pulleys, shafts, cylinders, mouldings, arches, wheel-windows, pillars, vases, ornaments, embellishments, etc.; then you will perceive how extensively this figure enters into design, and how it pervades all nature and the arts.

In Nature we nowhere find squares or rectangles; seldom, indeed, right lines. Curved and winding are all her outlines. Although straight lines may be considered beautiful, where they are necessary, yet curved ones are ever more pleasing to the eye. The circle and the ellipse (see conic sections) are a unity in themselves, and yet their boundary is ever varying, thus uniting what have been termed the "essential elements of beauty." A circle is symbolic of eternity, without beginning or ending.

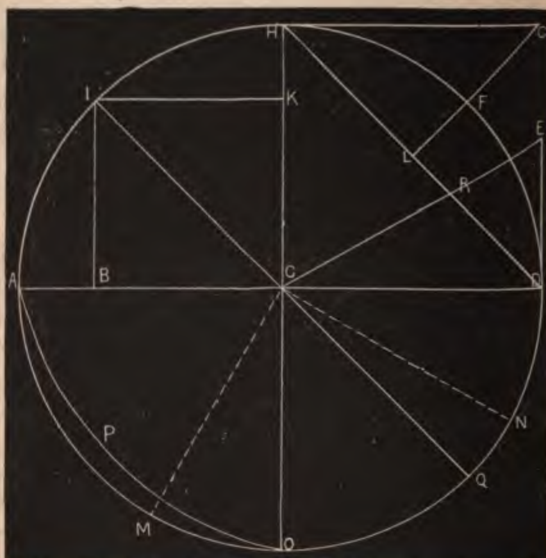


Fig. 37.

Geometricians define a circle as a plane figure bounded by a curve line, called the circumference, which is everywhere equidistant from a certain point within, called the centre. *Circum*, around, is a Latin preposition, used as a prefix in

many English words; *fero*, to bear, or carry, is a Latin verb, hence we get the words circumference, circumferential, circumferentor. The annexed diagram, Fig. 37, will assist in studying the nomenclature of a circle. C, the centre; ICQ, diameter; CM, radius; AI, arc; HLD, chord; HLDF, segment; AOD, semicircle; AOC, quadrant; ACM, sextant; ICH, octant; CMO, sector; AMOP, lune; HIQD, zone; HF, complement of an arc or angle; AIHF, supplement of the same; HG, tangent; LFG, secant; ED, co-tangent; CRE, co-secant; IK, sine; HK, versed sine; IB, co-sine.

Two circles having the same centre are termed concentric circles; otherwise eccentric circles, as the centre of formation and the centre of revolution in the eccentric of a steam engine. The circumference of every circle is supposed to be divided into 360 equal parts, called degrees; and each degree into 60 minutes; each minute into 60 seconds. Hence a semicircle contains 180 degrees, a quadrant 90 degrees, a sextant 60 degrees, and an octant 45 degrees. To reverse the order we may say that $60''$ (seconds) $= 1'$ (minute); $60'$ (minutes) $= 1^\circ$ (degree); 360° (degrees) $= 1$ circle.

The terms in the nomenclature of the circle, and their significance, will be more easily remembered, if the meaning of such words as chord, sine, co-sine, supplement and complement is understood, and still better if the diagram, Fig. 37, is repeatedly drawn out on the blackboard, or with the compasses on paper. Reference to any work on practical geometry will be sufficiently explanatory and helpful.

The following are some of the properties of the circle which are of greatest importance to the mechanical instructor:

The circle contains a greater area than any other plane figure bounded by an equal perimeter or outline.

The radius of a circle will go round its circumference six times.

The areas of circles are to each other as the squares of their diameters.

Diameter of a circle $\times$ 3·1416 = circumference.

Diameter of a circle $\times$ ·8862 = side of an equal square.

Diameter of a circle $\times$ ·7071 = side of an inscribed square.

Diameter^2 of a circle $\times$ ·7854 = area of circle.

Circumference of a circle $\times$ ·2821 = side of an equal square.

Circumference of a circle $\times$ ·2251 = side of the inscribed square.

Area of a circle $\times$ ·6366 = side of the inscribed square.

Side of a square $\times$ 1·4142 = diameter of its circumscribed circle.

Side of a square $\times$ 4·443 = circumference of its circumscribed circle.

Side of a square $\times$ 1·128 = diameter of an equal circle.

Side of a square $\times$ 3·545 = circumference of an equal circle.

Radius of a circle $\times$ 6·28318 = circumference.

Circumference of a circle $\div$ 3·1416 = diameter.

Any circle whose diameter is double that of another contains four times the area of the other.

Area of a circle is equal to the area of a triangle whose base equals the circumference, and perpendicular equals the radius.

The length of an arc may be found by multiplying together the number of degrees it contains, the radius and the number ·01745329.

Area of a polygon equals the radius of an inscribed circle $\times$ ½ number of sides $\times$ length of one side.

Rounding off Corners.

One of the most useful problems, and one that is constantly employed by architectural and mechanical draughtsmen, on account of its simplicity and handiness, is the one

given here. The object of its use is two-fold; one being to find the centre of the quadrant which is to take the place of a right angle, and another to ensure a good union between the straight and curved lines when "inking in."

Cases are constantly occurring where, for convenience or appearance sake, it is preferable to "round off the corners" in wood, stone, and iron work. Right angles and sharp corners in cast-iron work are generally avoided as much as possible, and, therefore, in making construction drawings, the draughtsman can very frequently use this simple problem as one that will prove to be of great assistance to him in more ways than one. For instance, in drawing anything of a rectilineal form, if it should be thought best not to have square but to have curved corners, the first thing to decide upon is the amount of curvature, which, of course, in this case, has to be a quadrant, or arc of a circle, equal to the fourth part of the circumference, and, therefore, a regular curve having a fixed centre and of definite radius. In determining the radii of corner curves, it is well to avoid the smaller fractions as much as possible. In most cases ¼″, ½″, ¾″, 1″, 2″, 2¼″, 2½″, etc., will answer just as well as 5-16″, 9-16″, 1 1-16″, 1 15-16″, 2 3-16″.

Fig. 38 illustrates just what we want to explain. Let BA, AB, represent the right angle (square) corner of a cast-iron plate, a wooden table, a pedestal base, or any other object. We will suppose that a curved corner is desirable, and that the radius shall be 1″. Take the pencil bows and open them to the extent of one inch. From A as a centre, and radius (one inch) AB, mark off on horizontal and perpendicular lines at BB. Without altering the opening of the compasses, from BB, as centres, draw arcs intersecting at C. C, then, becomes the centre of the arc, BB, of 90°. *The centre of the curve, therefore, has been found instantly, without trying or guessing.*

Another thing has been done. When inking in (curves and circles, as a rule, always being inked in first), two points have been given where to terminate the extremities of the arc, viz., BB; and consequently the straight lines can be drawn up boldly to BB, and will make what are termed "good joints." Of

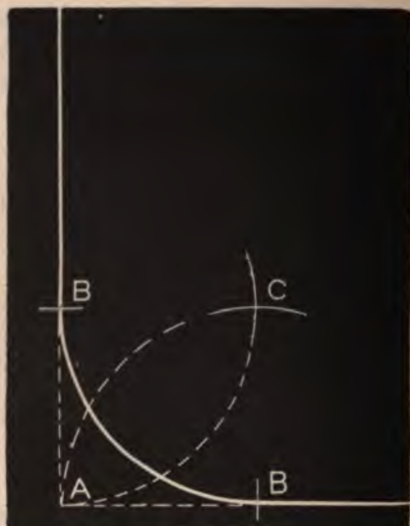


Fig. 38.

course this little "gem of a problem," as the writer terms it, is applicable to all four corners of the figure, or *wherever there is a right angle.* A good joint is one where the junction of lines is imperceptible; the compound line (a right line and curve) must appear as if drawn at one stroke, and similarly where there is a union of two curves.

How to Make Good Joints.

One of the points which distinguishes the careful and skilful draughtsman from those who are inexperienced and ill taught, is the art of making good joints. A practical illustration of the curved corners and good joints is given in the annexed diagram, Fig. 39, representing the outline of a locomotive tender tank. The problem we have given is applicable wherever a curve is seen to occur in this. To secure a good ink joint where two regular curves meet, always draw a

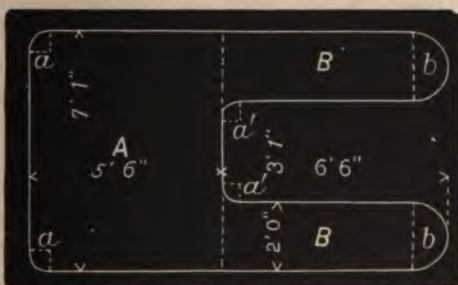


Fig. 39.

pencil line from the centre of one curve to the centre of the other. Where this line crosses, is the point of termination for both curves. In every case, draw a pencil line at the terminations of a curve, be it regular as the semi-circles and quadrants in the diagram given, or irregular as elliptical and parabolic ones exemplified in Grecian architecture. In the machinery constructed by the celebrated Whitworth & Co., of Manchester, England, graceful irregular curves enter into their designs far more than the combination of straight lines and arcs.

Use of Shadow Lines—Where to Place Them.

Let us first call attention to certain geometrical definitions and principles which, simple as they are, and probably familiar to most, should be constantly retained in the memory. Note the great variety of surrounding objects and their many different shapes, some large, some small. Here is a body of a single material, it may be of cast or wrought iron, brass, stone, or wood; there is another, constructed of various materials. Note, again, the many forms in nature and constructive art—of leaves, flowers, shells, and minerals; of houses, public buildings, machinery, household goods, and ornamental pottery. It is possible to represent these and all other objects on paper in outline by pen, or pencil, or brush. In the room where you are reading this, you will observe the difference in form between walls and tables, between chairs and windows, books and lamps. Now, there are only two kinds of surfaces, plane and curved. The edges of surfaces are *lines*. There are but two kinds of lines, straight and curved. There are but three kinds of straight lines, horizontal, perpendicular, and oblique. The edges of the pages of this book are lines. A postal card shows two plane surfaces, two horizontal and two perpendicular lines. A draughtsman's drawing triangle has plane surfaces, perpendicular, horizontal, and oblique lines. So all objects having plane surfaces are bounded by lines; the surfaces are terminated by lines. These lines, mathematically speaking, have length only; no breadth, no thickness. You cannot cut off or plane off a line. A line, therefore, is the edge of a surface. Examine architectural and mechanical drawings, and you will find that they are made up of curved and straight lines, which, in outline, *represent the edges of surfaces.* The form and shape of any plane surface is according to the di-

rection of its edges. The fewest number of straight lines that will make a figure, or the shape of anything, is three. You cannot make the shape of anything with two straight lines; with a curved and a straight line you can.

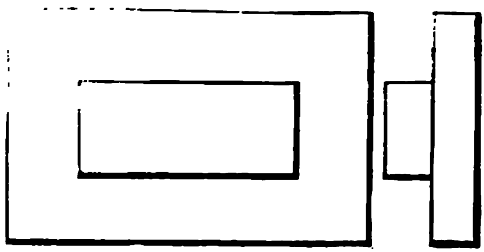
The student should, at the very outset, learn to sketch, and sketching, in practical draughting, consists in representing objects by means of pen, or pencil, or chalk, without the aid of instruments, and writing on the sketch the dimensions obtained by rule and calipers. In the annexed figures, it will be observed, that some of the lines are much broader than others. And just here it may be remarked, that the expressions "heavy," "thick" (lines), which appear in some works on drawing, are incorrect. It is correct to speak of fine lines, broad lines, but weight and solidity are scarcely applicable to such delicate work as geometrical delineation. In "Lessons in Mechanical Drawing," written by an eminent professor, who should be a good authority, these terms are used without distinction; heavy meaning a thick line, and a thick line meaning a heavy one. But to return to the broad lines. What are they for? Where are they to be placed? These broad lines are termed shadow and shade lines, and are, so to speak, the language of a drawing. They serve to show where shadows would occur from the objects themselves; they serve to show what is solid and what is hollow; what is a projection and what is an opening; what is a raised surface and what is a panel or recess. The shading lines show the curvature of a surface, whether it is convex or concave.

Light is supposed to fall at an angle of 45°, and to come from the upper right or left-hand corner. Where the light falls the lines are left fine, where shadows would occur the broad lines are introduced. The illustrations represent an oblong slot in a block, a circular hole in a plate, a projecting piece, and a circular "boss" on a plate. The student will

[illegible] the shadow lines are the reverse [illegible] surfaces. The circular shadow line is [illegible] backwards and for- [illegible] the radius of the circle in the opening [illegible] just inside the first one, of [illegible]

[illegible] shadow lines add [illegible] to the good appearance and

Fig. [illegible]



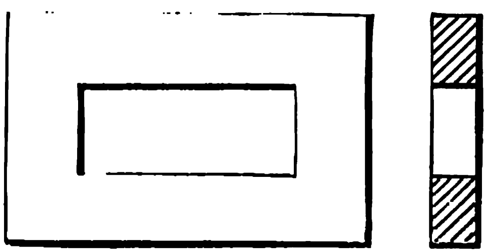


Fig. 41

[illegible] drawings, the use and disposition of them [illegible] thoroughly understood. Take, for instance, Figs. 40 and 41 [illegible] end and section view. [illegible] with fine lines of uniform

width, there would be nothing to indicate whether the interior lines represented the edges of a rectangular hole, or a rectangular raised panel giving another plane. But the addition of shadow lines makes this quite plain. In the figures given here the light is supposed to fall at an angle of 45° from the upper left hand; the shadows that would occur from the objects themselves would be where the broad lines are placed. In Fig. 40 the interior shadow lines are on the bottom and right-hand side, parallel with the outer ones. The fine lines are also parallel with each other. Now, if the exterior lines represent a rectangular solid, and the light is supposed to fall at 45°, it would fall on the upper surface and the edges on the left-hand side, and here are fine lines; where the light could not come, viz., the edges on the right-hand side, there would be shadows, and here the broad lines are placed. In Fig. 41 the interior shadow lines are just the reverse, being on the upper and left edges, indicating that there is a rectangular opening, and the shadows would be at the upper and left-hand side, just the reverse to the raised slab in Fig. 40. Therefore, without any other view, it is possible to know that in the first case the interior lines indicate a raised slab or projection, giving another plane; and in the other that the lines show edges of a rectangular opening.

The end view and section through the opening give the thickness of the object, and in the case of Fig. 40 the height of the secondary plane.

Figs. 42 and 43 illustrate the same thing, with the difference that the secondary plane and opening are circular instead of being rectangular, as in the first case.

One of the dotted diagonal lines (45°) serves as a guide to the termination of the shadow lines, and is drawn only in pencil and erased after inking in. It must be drawn through the new centre made to obtain the shadow line, and not

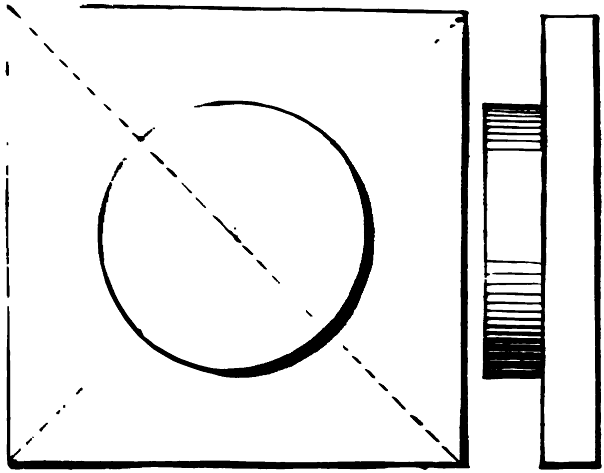


Fig. 42.

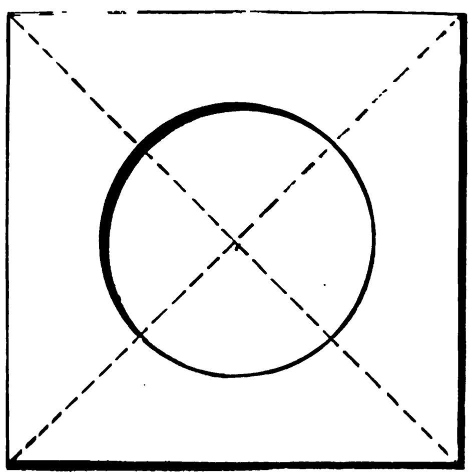


Fig. 43.

through the centre of the circle. It is this diagonal line drawn through the second centre which limits the movement of the bows in describing the semicircle, and is an assistance in making a good joint; the other diagonal line passing through the centre of the circle is the one on which the centre of the semicircle for the shadow line must be fixed.

Curved surfaces are indicated in line drawings much in the manner shown in the end view of Fig. 42. The best way to acquire expertness in this line shading, is to study some of the fine wood engravings in the English publications, *Engineering*, and *The Engineer*, or the cuts in some of our best industrial publications, or still better, mechanical drawings by expert draughtsmen.

Gearing.

The term gearing has various significations, and is extensively applied to different kinds of manufactures. For instance, we speak of the harness or tackle of beasts of burden as their gear; of purchases or tackles on board a ship as the gear. In steam-engine machinery we find certain parts spoken of and known as the valve gear, expansion gear, etc. But the term is most extensively applied to those parts of machinery where motion is communicated from one axis to another by means of cog or tooth wheels, or even by friction rollers.

Hence the term *spur gearing*, in which the teeth or cogs are placed round either the convex or concave surface of a cylindrical wheel, in the direction of radii from the centre of the wheel; *beveled gearing*, in which the teeth are placed on the exterior periphery of a conical wheel, in a direction converging to the apex of a cone, and the depth of tooth gradually diminished from the base; *frictional gearing*, by which motion

is communicated from one shaft to another by pressing into contact two cylindrical or conical rollers with smooth or corrugated surfaces.

Before undertaking to draw out spur and bevel wheels, the student must become familiar with certain technical terms and definitions that are inseparably connected with the delineation and subject of gearing. A *cog wheel* is the general name for any wheel which has a number of cogs or teeth placed round its circumference. When the teeth of a wheel are made of the same material and formed of the same piece as the body of the wheel, they are called *teeth;* when they are made of wood or some other material, and fixed to the circumference of the wheel, they are called *cogs.* A *pinion* is a small wheel. When two toothed wheels act upon one another, the smallest is generally called the pinion. The terms *trundle* and *lantern* are applied to small wheels having cylindrical bars instead of teeth. We speak of *trundle wheels, lantern wheels.*

The teeth in pinions are sometimes termed leaves; in a trundle, *staves.*

The wheel which acts is called a *leader* or *driver;* and the wheel which is acted upon by the former is called a *follower*, or the *driven.* When a screw or *worm* revolves in the teeth of a wheel, the latter is termed a *worm wheel* or *worm gear.* When a pinion acts with a rack having teeth, we speak of *rack* and *pinion.* When the teeth are on the inside of the rim, and not on the periphery, the wheel is termed an *internal gear.* A *crown wheel* has its cogs or teeth at right angles to its plane.

Two wheels acting upon one another in the same plane are called *spur gear;* the teeth are parallel with the axis. When wheels act at an angle, they are called *bevel gear. Miter wheels* are bevel wheels of the same size, working at right angles with one another; angle of teeth 45°.

There is a variety of gear wheels, as, for instance, plate wheels, which have solid bodies, and arm wheels that have three, four, six, or more arms between the hub and the rim.

We now refer to the diagram, Fig. 44; that is a perspective view of two adjacent teeth on the periphery of a spur wheel. We call attention to this simple representation as preparatory to drawing out a spur wheel.

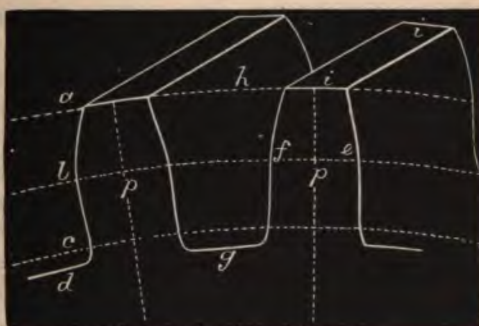


Fig. 44

The "periphery" of a wheel is the extreme circumference. The "pitch line" or "pitch circle" is supposed to be the working circle. The working circles of two spur wheels "in gear" would be represented by two circles tangent to each other. The pitch line is a most important one in gearing. The diameter of both spur and bevel wheels is measured and calculated neither from the outside nor from the bottom of the teeth, but on the pitch circle. When we speak of the diameter of a spur or bevel wheel, we mean the diameter of the pitch circle, without any reference to the form of tooth. It is on this circle that the centres of the teeth are spaced off. The diagram may be referred to as an illustration:—*a* is the

periphery; *b*, the pitch line; *c*, the working depth; *d*, the root of the tooth or cog; *e*, *f*, the thickness; *g*, *h*, the whole length; *i*, *i*, the breadth of each tooth; *p*, *p*, the pitch of the teeth, that is from the centre of one tooth to the centre of the next on the pitch circle.

Commencing at the centre, a spur wheel may be said to consist of a hole, square, octagonal or round, for its axle or shaft; a hub; the web, body or arms; a rim, and the teeth. The fundamental circle is the pitch circle on which the teeth or cogs are set out by the draughtsman and the pattern-maker, and by the diameter of which, or the number of teeth on it, computations relative to proportion, speed and strength are made.

The number of teeth, their proportions, pitch and diameter of pitch circle are frequently determined on the "Manchester" principle. This system originated in Manchester (Eng.), and is the one long adopted by the makers and users of cotton, flax, wool and other machinery, including tools for iron and wood. It is now far more generally used in this country than formerly, more, however, for determining diameters and number of teeth, which, of course, regulate speeds, than for proportioning the size of teeth on the wheels themselves. The system is a simple and easy one, applicable in cases where there are trains of wheels on different planes, and which planes vary from each other in the coarseness or fineness of the pitch of wheels.

For instance, in the construction of different systems in flax machinery, there are "breakers," "hackling," carding, drawing, roving and spinning machines. These require great numbers of gear wheels, as their cylinders and rollers have different speeds, and each system requires coarser or finer gears. An English mill-owner in ordering his machinery particularizes what gearing he wishes, thus: "Gearing to be 6

per inch," or "8 per inch," or "10 per inch," and the maker of such machinery understands at once the degree of coarseness or fineness of the wheels, amounting in number sometimes to several hundreds. The principle is not applicable to large wheels, but is limited in its application to small wheels, or wheels having "fine pitch," as will be seen in the following explanation, which we introduce as very useful and indispensable knowledge for the acquisition of the student in mechanical drawing.

The "pitch" of teeth has already been stated to be the distance from centre of one tooth to the centre of another on the "pitch line," measured on the chord of the arc. In determining, however, the number of teeth or pitch of wheels on the "Manchester" principle, the pitch is reckoned on the *diameter* of the wheel, in *place of the circumference*, and distinguished as wheels of "4 pitch," "6 pitch," "8 pitch," etc. In other words, this means that there are four, six, or eight teeth in the circumference of the wheel for every inch of diameter; hence the technical term "*diametral pitch*" in distinction from "*circular pitch*." Suppose the diameter of the pitch circle to be divided into as many equal parts as there are teeth to be given to the wheel; let one of these parts be called the "*diametral pitch*," and let a few definite values in terms of the inch be assigned to it; then it is clear we have this relation:—Diameter, divided by the number of teeth, equals the diametrical pitch; and as the diametrical pitch is always a simple fraction of an inch, we get the following general expressions:

I.—Number of teeth = pitch $\times$ diameter.

II.—Number of teeth divided by the diameter = pitch.

III.—Diameter = number of teeth divided by the pitch.

For an arithmetical example of the foregoing rules let it be assumed that a wheel of 24 inches diameter is required to

have 96 teeth. By expression II we have $96 \div 24 = \frac{1}{4}$; that is to say, the diameter being divided into equal parts, corresponding in number to the number of teeth in the circumference of the wheel, the length of each of these parts is $\frac{1}{4}$ inch. Consequently the diametrical pitch is *four pitch*, or, in workshop phraseology, "4 *per-inch pitch*." Taking expressions I, II, III, as verbally written, and transposing for this wheel into figures, we have: (I) $4 \times 24 = 96$ teeth. (II) $96 \div 24 = 4$ pitch. (III) $96 \div 4 = 24''$ diameter.

The "circular pitch," corresponding to this "diametral pitch," is found by the properties of the circle (previously explained) to be $\frac{1}{4}$ or $\cdot 25 \times 3\cdot 1416 = \cdot 785$, or a little more than $\frac{3}{4}$ of an inch from the centre of one tooth to the centre of another on the pitch circle.

In setting out a wheel on the "Manchester" principle, it is convenient to know what the circular pitch will be when the diametral pitch is fixed upon. Suppose a wheel is wanted, or a system of gearing, which is to be 8 per inch. The diameters are easily found by dividing the number of teeth by 8; for instance, wheels having 64, 56, 48, 32, and 16 teeth, respectively, would be 8″, 7″, 6″, 4″, 2″, diameter of pitch line; but unless the circular pitch is known, the pitch circle would have to be spaced off by repeated trials to get in the required number of teeth. The table on page 65 will be found useful.

From this table it will be at once apparent when the diametral pitch and the diameter of the pitch circle are known, the circular pitch can be taken in the dividers and the centres of the teeth spaced off (approximately) at once upon the pitch line.

Wheels of this description have generally their teeth cut in a gear-cutting machine; patterns with teeth of fine pitch are seldom made. Therefore in practical draughting it is usual to draw out a segment of the wheel and show part of the rim

and a few teeth only. The diameter, pitch, number of teeth, width of face, size of hole, diameter and length of hub should be distinctly given.

Table No. 1.		Table No. 2.	
Diametral Pitch.	Circular Pitch.	Circular Pitch.	Diametral Pitch.
2	1·57	1 3-4 inch.	1·79
2 1-4	1·39	1 1-2 do.	2·09
2 1-2	1·25	1 7-16 do.	2·18
2 3-4	1·14	1 3-8 do.	2·28
3	1·04	1 5-16 do.	2·39
3 1-2	·890	1 1-4 do.	2·51
4	·785	1 3-16 do.	2·65
5	·628	1 1-8 do.	2·79
6	·523	1 1-16 do.	2·96
7	·448	1 do.	3·14
8	·392	15-16 do.	3·35
9	·350	7-8 do.	3·59
10	·314	13-16 do.	3·86
11	·280	3-4 do.	4·19
12	·261	11-16 do.	4·57
14	·224	5-8 do.	5·03
16	·196	9-16 do.	5·58
18	·174	1-2 do.	6·28
20	·157	7-16 do.	7·18
22	·143	3-8 do.	8·38
24	·130	5-16 do.	10·06
26	·120	1-4 do.	12·56
28	·112	3-16 do.	16·75
30	·104	1-8 do.	25·12
32	·098	1-16 do.	50·24

On reference to the table of diametral and circular pitch, it will be observed that the circular pitch of the first few numbers may be properly considered as among coarse pitch

wheels, and therefore the statement, "Wheels of this description generally have their teeth cut in a gear-cutting machine," etc., may be modified by saying that wheels of medium and fine pitch are generally cut in a gear-cutting machine.

The improvements in gear-cutting tools allow the teeth of wheels of medium pitch to be formed far more exactly by a revolving cutter than when cast from a pattern. In England, the Manchester principle is not, if we remember right, carried beyond four per inch. The rule, at one time, for proportioning the teeth of fine gears, and practiced by some celebrated makers of flax and cotton machinery, was: Divide an inch into the same number of equal parts as the diametral pitch; set off one of those parts above the pitch circle, one and a half parts below the pitch circle, and thickness of tooth equals also one and a half parts. For example: To proportion teeth for wheels ten per inch, one inch would be divided into ten equal parts, then one-tenth would be set off above the pitch circle for the upper part of the tooth, and one and one-half tenths below the pitch circle for the lower part of the tooth, and the thickness also one and a half tenths. This proportion gives a good deal of clearance; but in machinery operating upon dusty and fibrous materials, this clearance was found necessary to prevent the spaces from being clogged up with refuse. Most of the wheels, fine as they were, were cast from patterns, and the teeth merely cleansed by brushing and slight filing.

There are boxwood and steel scales to be had by which the diameters of pitch circles for wheels on the Manchester principle can be measured off at once.

The modern practice is to have the teeth of all wheels of fine pitch cut in a gear-cutting machine whenever smoothness and accuracy of operation are required. Among the best

examples of a large system of "machine-cut gears" are those on the large "lightning" and other printing presses constructed by R. Hoe & Co., of New York; on the machine tools constructed by Whitworth & Co., of England; Sellers, of Philadelphia; the Pratt & Whitney Co., of Hartford; and Browne & Sharpe Manufacturing Co., of Providence, R. I.—firms who have given especial attention to the construction of fine gear wheels, and have invented beautiful mechanism for ensuring accuracy in their operation. The student will do well to observe the form of teeth in wheels by these makers.

Next in order are the proportions and the calculations connected with gear wheels of *coarse* pitch. The "setting out" or drawing of teeth requires extreme accuracy, and before attention is given to the delineation of sections, plans, side and front views of a spur, and a bevel wheel, the student must know what the essentials are in draughting them. We are aware that this subject of gearing has received much attention from able mathematicians and mechanics. Numerous elaborate treatises have been published about it, some of them only intelligible to expert mathematicians; but there are also other systems introduced by thoroughly practical engineers, which enable the formation of the teeth of wheels to be done in a simple manner. But after all that has been said and done, a variety of opinions exist, and there may be those who can show a still more excellent way.

Reference being made to the last diagram, representing two contiguous teeth of a wheel, and bearing in mind the nomenclature connected with it, we now give certain proportions for teeth of wheels.

Let the wheel be of any required pitch; then for proportions of tooth:—From periphery to pitch line = 3-10ths of pitch; working depth = 6-10ths; bottom clearance = 1-10th;

whole depth = 7-10ths; width of space = 6-11ths; thickness of tooth = 5-11ths.

Another proportion:—Divide the pitch into 15 equal parts; then from periphery to pitch line = 5½ parts; depth from pitch line to root = 6½ parts; whole length = 12 parts; working depth = 11 parts; thickness of tooth, arms and rim = 7 parts; width of space = 8 parts.

Proportions for wheels with flat arms in the middle of the ring, and ribs or feathers on each side:—The length of the teeth = 6-9ths of the pitch, besides clearance, or 5-7ths of the pitch, clearance included.

Thickness of the tooth............	4-9	the pitch.
Breadth on the face..............	2 1-2	"
Edge of the rim.................	4-9	"
Rib projecting inside the rim.......	4-9	"
Thickness of the flat arms.........	4-9	"

Breadth of the arms at the points = 2 teeth and ¼ the pitch, getting broader towards the centre of the wheel in the proportion of ½ inch to every foot in length. Thickness of the ribs or feathers ¼ the pitch. Thickness of metal round the eye, or centre, 7-9ths the pitch. For wheels made with plain arms, the teeth are in the same proportion as above; the rim and the arms are each equal to one cog or tooth in thickness, and the metal round the eye same as above in feathered wheels.

To find the breadth of the teeth:—Divide the horse power by the velocity of the wheel at the pitch circle, per second in feet; twice the quotient is the breadth in inches. Example—Required, the breadth of the teeth for a first mover from a 15-horse engine; the velocity of the wheels being 6 feet per second. Answer:—$15 \div 6 = 2{\cdot}5 \times 2 = 5$ inches.

The construction and forming of the teeth in different pat-ns of gearing is such an extensive and important depart-

ment of machine work, that it demands special care from the student. We therefore give here the system which has been worked out and perfected by Mr. John Walker, of Indianapolis, Ind. This system is the result of much research and careful practical application, and thousands of gears have been

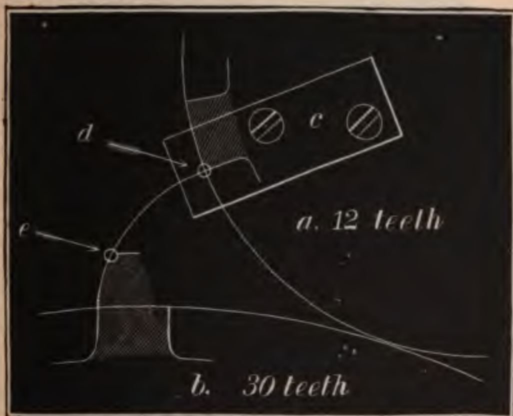


Fig. 45.

determined by it in this country and England, and many flattering testimonials have been received of their easy and almost noiseless working.

The curves from which this system is determined are known as the epicycloid, for the faces of teeth, and epitrochoid, for the flank of teeth. Figs. 45 and 46 will serve to explain the method of generating the curves. No rolling circles are used. The pitch circles generate for themselves in this system as they do in actual service in all gears. In figures mentioned two templates, *a* and *b*, are provided, representing gears with pitch diameters respectively of 12 and 30 teeth, one inch pitch.

A piece of wood, *c*, is attached to template, *a*, in Fig. 45, to carry a marker, *d*, to generate face of tooth for gear of 30 teeth; the marker, *d*, representing side of tooth of 12-tooth pinion, will generate a face for gear of 30 teeth that will precisely contour with flank of 12 pinion, when said flank is generated with a marker placed at *e*. In Fig. 46 the piece of

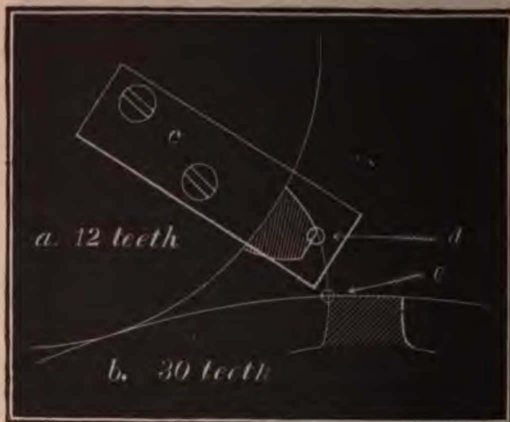


Fig. 46.

wood, *c*, is attached to template, *a*, to support marker, *d*, outside of pitch circle. The position of marker represents end of tooth, and will generate a flank for a gear of 30 teeth that will contour with face of pinion tooth when said face is generated with a marker placed at *e*. By this method of generating, any pair of gears intended to work together will work absolutely correct, with true velocity ratio, and if necessary, without any clearance at sides or base of teeth. Gears thus generated only work in pairs. In practice the objection to this is that gears so determined will not interchange. The

system about to be explained overcomes this difficulty in a very ingenious manner, and at the same time gives as near an approximation to the true curvature as generated by pitch circles already explained.

Suppose, as in Fig. 47, that the pitch circle is for 200 teeth,

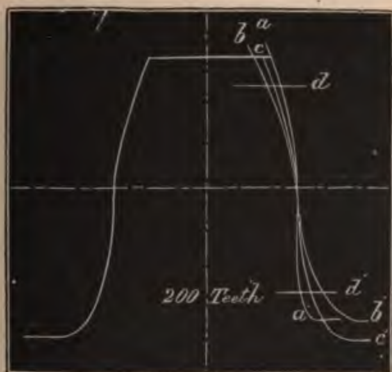


Fig. 47.

two-inch pitch, the curve, *a a*, is generated as already described by using a generating circle equal in diameter to 200 teeth, two-inch pitch, the curve, *b b*, is generated as already described, by using a generating circle equal in diameter to 10 teeth two-inch pitch. These lines, *a a* and *b b*, are the two extreme forms of teeth for a gear of 200 teeth, two-inch pitch, supposing 200 to be the highest and 10 the lowest number of teeth to be used for general purposes. The line, *c c*, is a medium or average line of the two extremes, which is found by using nearest radii to the curves. Accepting the distance from pitch line to intersecting lines, *d d*, as that portion of the tooth is most in contact, it is necessary to accept this intersecting point where the average can be taken, on account of

having to allow clearance at bottom of tooth. It will be understood that the average line, *c c*, extends beyond *d d*. It is impracticable to average that portion of flank below *d*, on account of having to give clearance at base of teeth. That portion of face above *d* is caused to be slightly smaller than the average. This is claimed to be a practical advantage, as

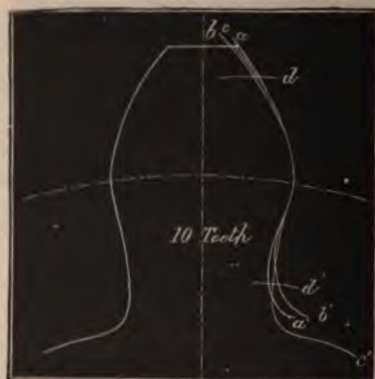


Fig. 48.

it allows that part of face of tooth above *d* to get within the pitch circle of the opposite gear before coming in contact. This is necessary in cast gearing on account of inaccuracy of pitch in patterns, or straining of teeth in molds during casting. Fig. 48 is a similar illustration to Fig. 47, and the foregoing explanation is adapted to both illustrations, save that the pitch circle is for 10 teeth, two-inch pitch, the curve, *a a*, being generated with pitch circle of 200 teeth, two-inch pitch, and curve, *b b*, with generating pitch circle of 10 teeth, two-inch pitch. It must be understood that whatever number of teeth the gear may contain, the 200 teeth and 10 teeth gener-

ng pitch circles must always be used. The average being :en in all cases, the gears will interchange without deviating terially from the true epicycloidal curves for faces, and epi-choidal curves for flanks, or true curvature as generated :h pitch circles only, of which this is the nearest practical proximation.

Fig. 49.

Those who are conversant with this subject will see at once naterial difference between the system here explained and at known as the Willis or Odontograph; he adopting a gle generating circle, the diameter of which is equal to the lius of the smallest gear in the set. Why such a generating cle is used on a pair of gears of 200 teeth, intended to rk together, we are at a loss to know, when the true form n only be generated by the two pitch circles being rolled gether. We presume, by the above, that the 200 is pre-red to work with 10; but the 200 is not prepared to work th one of its own size, or any other but the 10. By the

Fig. 50.

Willis system we have a wedge-shaped tooth for all gears, which has a strong appearance; but in practice this amounts to nothing, for they have less teeth in contact than those of a true epicycloidal and epitrochoidal form generated by pitch circle, which, although smaller at the root, has more teeth in contact, distributing the strain over a larger portion of the rim. At the same time, there is not the objection in working out of gear, as in the Willis, which is caused by the thrust from the wedged form of tooth wearing the boxes. It is evident that the thrust is as the incline of the surfaces of the teeth to the line of centres of both shafts. In pinions the Willis system has the reverse; viz., a very weak tooth at the root. Pinions ought to be as strong as possible (without injury to their form), on account of having but one or two teeth in contact.

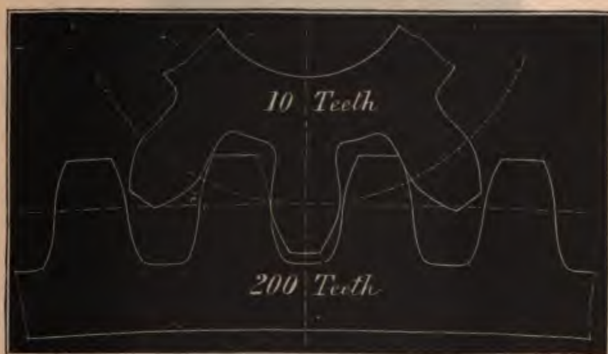


Fig. 51.

Figs. 49, 50, and 51, are illustrations of extreme numbers of teeth in gear. Determined by this (Walker's) system, it will be observed that the form of teeth in the pinions of 10 teeth are all alike; also the form of teeth for gears of 200 teeth

Fig 52.

are alike. These two extreme numbers of teeth have been selected for illustration, as they are really the worst cases to determine. All other numbers of teeth are as the difference of their diameters, the difficulties lessening as the gears approach an average of the two extremes.

In delineating the form of teeth, and finding the respective radii for the average line, as explained in Fig. 47, the inventor used templates of six-inch pitch for gears of 10, 12, 15, 20, 30, 50, 100 and 200 teeth, also a rack. The forms of teeth were found for each gear by using pitch circles of 10 and 200 teeth respectively, as in Fig. 47, for the generating circles, they being chosen before as the limits. To determine the teeth of

Fig 53

gears by this plan would be tedious. To obviate this the inventor has arrranged a very complete and convenient chart or scale, known as Walker's Wheel Scale, whereby any person with ordinary mechanical ability may delineate in a few moments the proper form of tooth for any particular gear needed.

Fig. 52 is an illlustration of chart or scale. From the portion A we get the length of tooth for any gear; from the portion B we get half thickness of tooth on pitch circle; from portion C we get half thickness at root for any gear; from portion D we get half thickness of tooth at point. These half thicknesses are set off on each side of centre or radial line, as in Fig. 53. Fig. 55 is a complete illustration of three teeth determined from the scale for a spur gear of 1⅛ inch pitch, and

Fig. 54.

60 teeth. The pitch arc, *a a*, being struck with proper radius, draw radial line, *b b*, from scale set off, *a c* and *a d* forming lengths of flank and face respectively; from scale set off, *b e*, *b f*, *b g*, on each side of radial or centre line, forming thickness at pitch line, root, and point of tooth; then with radius, *c h*, for flank of tooth taken from scale for a gear 1⅛ inch pitch and 60 teeth, intersect arcs at *c* from *e* and *f* on both sides of tooth; these intersections indicate position for path of centres for striking the flanks of the teeth. Then with radius, *c i*, for face of tooth taken from scale, for a gear 1⅛ inch pitch and 60 teeth, intersect arcs at *c* from *e* and *g* on

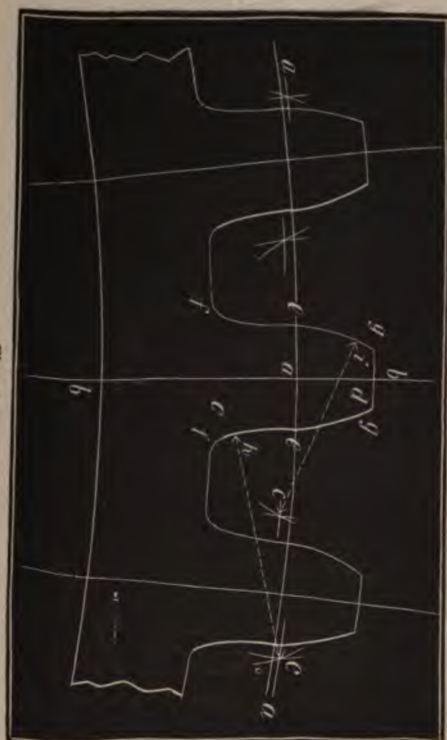


Fig. 55.

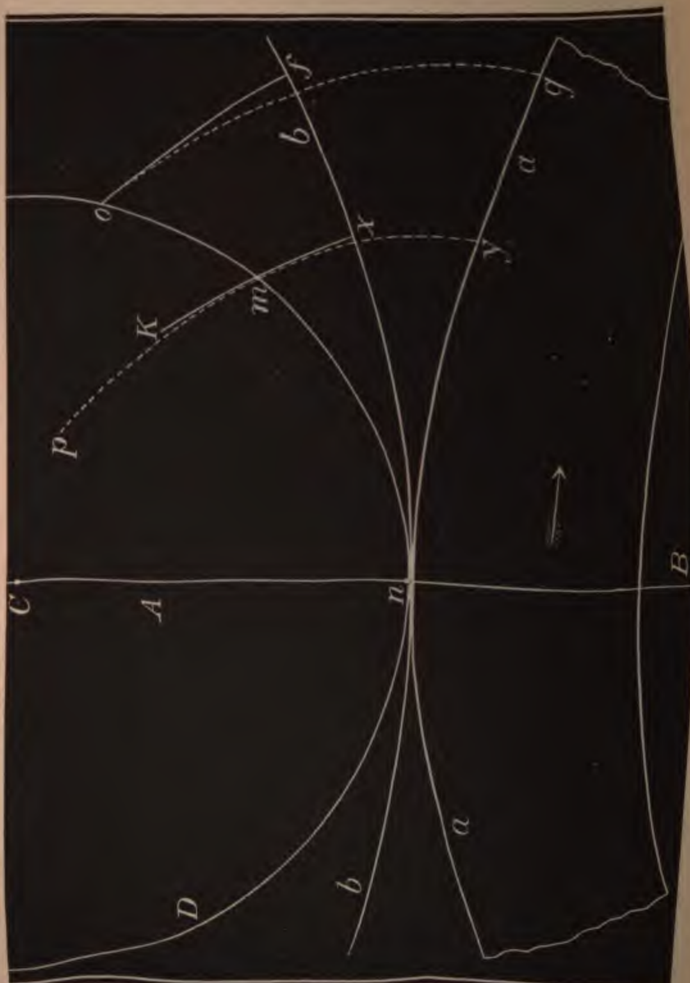


Fig. 56.

both sides of tooth. These intersections indicate position for path of centres for striking the faces of the teeth. The fillets at the roots of teeth are struck with radii provided for on scale. In determining gears with less than 30 teeth, as in Fig. 55, arcs, *e e*, struck with radius equal to half thickness of tooth are used across pitch line, allowing the arcs forming flanks and faces of teeth to blend with them. The form of teeth from this system are such as to roll easily on each other without jarring.

Curves for the Teeth of Gear Wheels.

The following discussion of the teeth of gear wheels is from the advance sheets of a work on "Mechanical Manipulation," by Joshua Rose, M.E., and should be carefully studied by all practical draughtsmen:

That the curves of the teeth of gear wheels may be so formed as to give to the wheels as uniform and equal velocity as they would receive if motion was communicated by reason of the frictional contact of their smooth circumferences, may be proved as follows: In Fig. 56 let *a a* and *b b* represent the pitch circles of two wheels free to rotate about their centres, which are fixed on the line *A B*. Let *C* be the centre of a rolling circle, free to rotate about its centre, on the line *A B*. Let *n* be the point of contact of all three circles. Suppose *b b* to be the pitch circle of an internal or annular wheel, the convex side of which is in contact with *a a* at *n*, while the concave side is in contact with the rolling circle, *D*, at *n*. Let the dot at *n* represent a tracing point fixed on the generating circle. If rotation be given to *a a* in the direction of the arrow, it will, by reason of its contact with *b b*, communicate to *b b* a velocity equal to its own, and *b b* will communicate the same velocity to the circle *D n m* (the lines being supposed to have no sensible breadth),

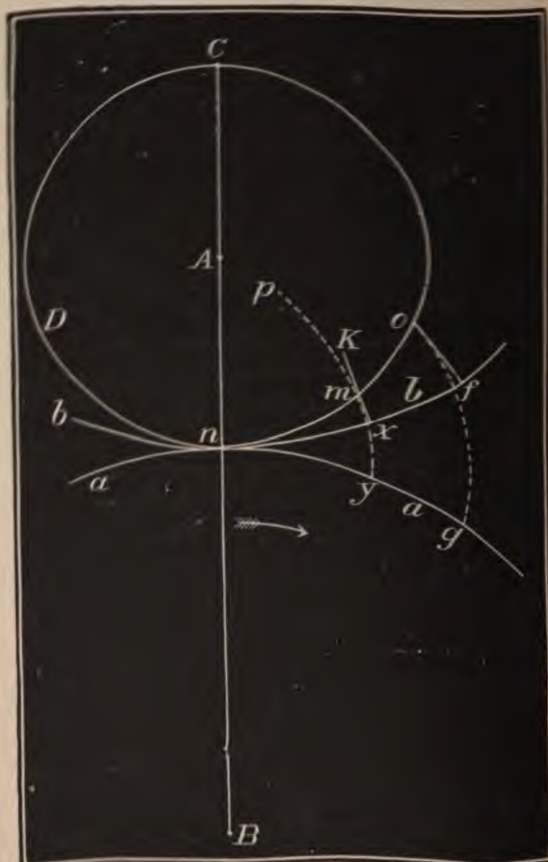


Fig. 57.

hence the three wheels would rotate with the same velocity. As these circles rotate, the point, *n*, will recede from the line of centres, and will also recede from the circumference of the two circles.

If, as it moves, it be capable of marking its path, it will be found on reaching it to have marked inside the circle, *b b*, the curve denoted by the full line, as *m x*. And simultaneously with this curve it has marked another curve *outside* of *a a*, as denoted by the dotted line, *m y*. Rotation being continued, when the tracing point has reached *o*, it will have continued the same curves as *o f* and *o g*.

Now, since both these curves (*o f* and *o g*) were traced by one and the same describing point, and at the same time, it follows that at every point in its course that point must have touched both curves at once, and it is obvious that the curves must always be in contact or coincide with each other at some point on the path of the describing point, which may be at any point on the line *n m o*.

Now *a a* having had a constant and uniform velocity, while the curves *k m x* and *p m y* had constant contact, it is evident that if *p m y* were a tangible surface (as the face of a tooth on *a a*) and *k x* were a tangible surface (as the face of a tooth on *b b*), the same uniform motion may be transmitted from *a a* to *b b* by pressing *p m y* against *k x*.

The line, *n m o*, is thus the locus of contact, or, in other words, the locus of contact is always on the line of the rolling circle when that circle has its centre coincident with the line of centres of the two wheels.

In this example the diameter of the rolling circle was one-third that of the pitch circles, *a a*, *b b*; but the same rule holds good if the diameter of the rolling circle be one-half, as in Fig. 57, or three-fourths, as in Fig. 58, that of the base

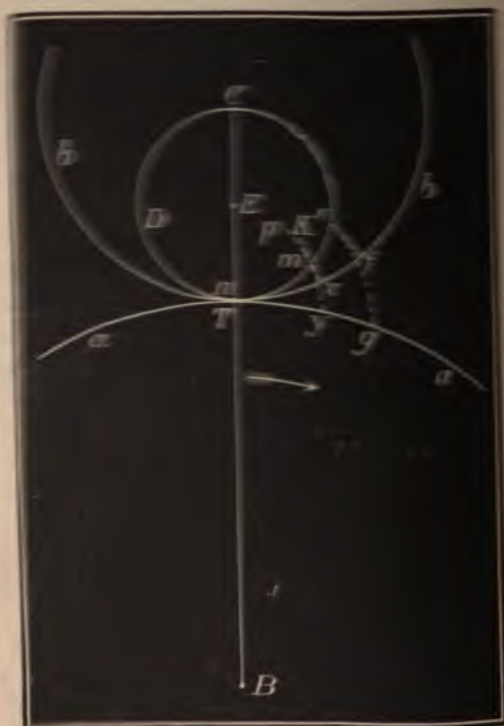


Fig. 58.

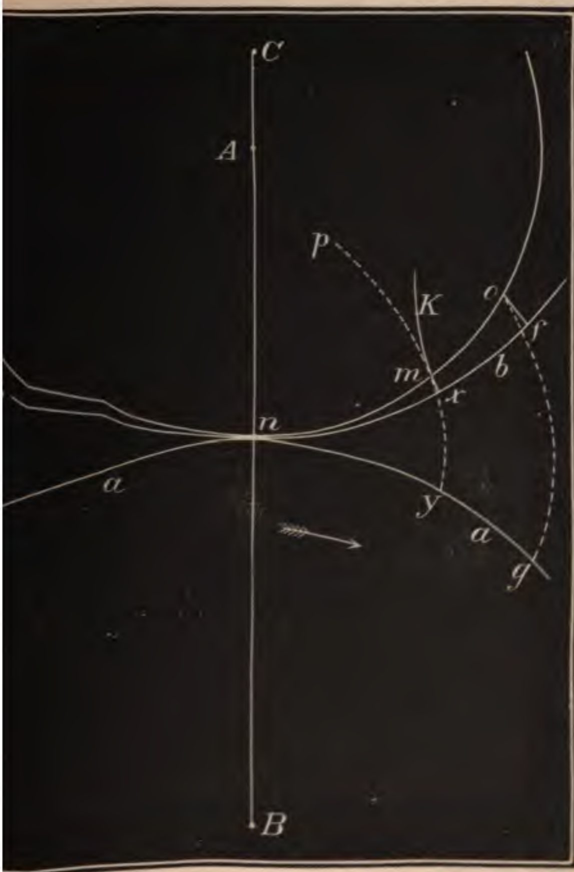


Fig. 59.

circle, the explanation given with Fig. 56 applying (the letters of reference being the same in all the figures).

Suppose now that the diameter of the follower (or driven wheel) be diminished to one-half that of the driver, as in Fig. 59, the rolling circle being made one-half that of the follower, still the same rule holds good, for the pitch circle, *b b*, Fig. 59, would still move with the same linear velocity as *a a*. It will not change the matter if the radius, *n B*, instead of being twice that of *B*, should be an infinite distance from *n a a*, becoming a straight line, or the pitch circle of a rack, as shown in Fig. 60 (where the same letters of reference are used), in which a line, *C B*, perpendicular to *a a*, may be taken as the line of centres.

Proportion for the Teeth of Gear Wheels.

In order to secure good wheels, it is as essential to have good proportions as a good form of tooth. The proportions of wheels are very varied, seeming sometimes as though the teeth had no relation to the rim, the rim to the arm, or the arm to the hub. The pitch and breadth of a wheel having been determined for a given amount of work, we propose to determine all other parts of the wheel to have a relative proportion. The breadth of wheels vary from twice to four times the pitch, according to circumstances; but a good proportion is three times the pitch. The following proportions for ordinary wheels will be found very convenient and correct:

Breadth of wheel........................	= pitch × 3·00
Pitch line to point........................	= pitch × 0·35
Pitch line to root........................	= pitch × 0·4
Thickness of tooth on pitch-line..........	= pitch × 0·475
Space between tooth on pitch-line........	= pitch × 0·525
Thickness of rim........................	= pitch × 0·5

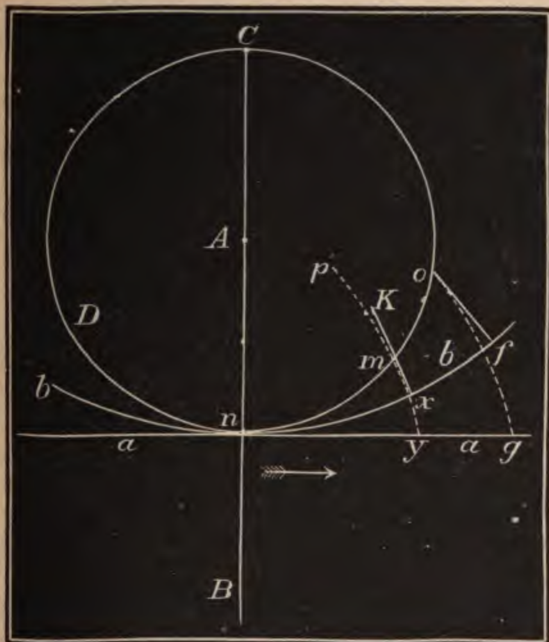


Fig. 60.

Thickness of flat arms....................	= pitch × 0·5
Thickness of feathers....................	= pitch × 0·375
Width of feather around rim..............	= pitch × 0·65
Width of feathers at pitch-line............ —increasing towards hub 1 in. per foot.	= pitch × 1·25
Metal around eye for flanged hub..........	= pitch × 0·575
Thickness of flanges.....................	= pitch × 0·5
Projection of flanges around hub..........	= pitch × 0·875
Metal around eye for plain hubs...........	= pitch × 0·75
Radii for fillets joining feathers to rim for all number of arms.....................	= pitch × 0·75
Radii for joining feathers at hub... 4 arms	= pitch.
" " " ... 5 arms	= pitch × 0·9
" " " ... 6 arms	= pitch × 0·8
" " " ... 7 arms	= pitch × 0·75
" " " ... 8 arms	= pitch × 0·65
" " " ... 9 arms	= pitch × 0·6
" " " ...10 arms	= pitch × 0·55

In ordinary bevel-wheels, the form of the back of arms is found by using radii equal to face of wheel, using the lower corner of back of iron for the centre. This gives a uniform rise to the back of all wheels, at the same time makes the arms the same width as face of wheel. When a wheel has a special form of arms, the radii are altered; but always have their centre on the line forming back of rim. Flanged hubs, as given in the foregoing proportions, are superior to plain hubs, having the required strength with uniformity of metal, avoiding straining. The cross-section of arms and rim in all mitre and bevel-wheels should be radial lines to insure equal proportion of metal.

MORTISE WHEELS.

Thickness of rim........................	= pitch.
Thickness of iron tooth..................	= pitch × 0·4
Thickness of wood tooth.................	= pitch × 0·566
Clearance...............................	= pitch × 0·033
Mortise in wheel........................	= pitch × 0·5
Shoulders around cog....................	= pitch × 0·033
Metal at ends of mortise................	= pitch × 0·5

In bevel mortise-wheels, the bevel at the small end of the mortise will decrease with the pitch. The best of hickory, beech and maple bear a proportion of strength of about 1·25 to 1· of cast iron. From the foregoing proportions, it will be observed that the mortise of the mortise-wheel bears this proportion to the thickness of the tooth (or pitch line) of the iron wheel—the tenon of the cog being the weakest part. It will be found that after the mortise-tooth has worn away the thickness of the two shoulders, it will be as strong as the iron tooth. The proportions are made so that the root part of the mortise-tooth may be straight or curved. Less clearance is required for mortise-wheels than ordinary cast wheels.

Delineation of a Spur Wheel.

Fig. 61 gives two views in elevation—a vertical section at the centre, and a transverse or cross section of one of the arms of a spur wheel. From this plate the foregoing description of the various parts in spur gears can be better understood, as they are represented here in combination, and the wheel in its entirety. The first view to be drawn is the side one, showing all the teeth, hub, arms, etc.; from this the other elevation and sections are obtained. Having determined the number of teeth, the pitch and the diameter of the pitch circle, the last must be described by the pencil bows

Fig. 61.

with a fine, distinct, even circle. Draw through the centre of this circle a vertical and a horizontal line, extending the latter freely for the other views. Upon the pitch circle, commencing at some point where the horizontal or vertical line intersects it, space off the centres of the teeth. This should be done with the spring dividers or hair-spring compass, which will allow of nice adjustment. In spacing off this or any other circle or line, the dividers must be held between the finger and thumb, and not turned over or revolved between them at every spacing, in one direction, which will roll the instrument upwards in the hand, but the motion must be alternated first above, then below the line; this enables the handle of the instrument to be retained at the extremities of the finger and thumb, and be perfectly controlled under delicate handling. Spacing off the centres of the teeth must be done with exactness, and may require a few trials before the pitch circle is divided into the required number of exact equal spaces, but it must be done at the expense of patience and perseverance. The breadth of a line will make a very perceptible difference in the result when it is multiplied several times on a circle or a straight line. The centres being given, lines may be drawn through them radiating from the centre. Upon one of them the length of a tooth may be set off, according to already given or other proportions—so much above and so much below the pitch circle; then a circle is to be drawn for the periphery or extreme outside, and another for the bottom of the teeth. The thickness is next in order according to determined proportions, and taking half of this in the dividers, it must be set off on each side of the radiating centre lines on the pitch circle. Examine the teeth on the horizontal and vertical centre lines in the plate. The curves of the teeth are to be put in next, and if these are not found in the way described by Walker's or other systems, the curves must be arcs

that approximate as closely as possible to the true working curve; these arcs have of course fixed centres, and are of equal radii. The hub, eye, arms, and rim, are next drawn in, and an examination of the plate will suggest how they should be represented. This view gives all the diameters, the width of the arms at hub and rim, the depth of the key-seat, etc., but does not inform what the width or face of the wheel measures, or the length of the hub. The other elevation does this. Here the teeth are shown for the sake of completeness, but in practice are not really necessary. The lines representing them are projected from the points of the teeth in the side view, as indicated by the dotted lines.

The vertical and cross-section views of the arms give width and thickness. The transverse section of the arm shows the form of the arm at points on the short vertical line in the side view. This short vertical line is connected with the cross section by dotted lines.

Now these fine dotted lines, shown in this and succeeding plates, are termed reference or projection lines. They are of great use in making a drawing intelligible by pointing out the different views of the same pieces or parts. Some difference, however, must be made between centre lines, dimension lines, and projection lines. A good plan is to draw all centre and radii lines full, but finely, without dotting, in red ink (carmine), or in crimson or scarlet lake (water colors); the projection lines in coarse broken blue, and dimension lines in fine dotted blue. Blue ink, or Prussian blue (water color) are used for the latter purpose. Concealed parts—parts that it is desirable to indicate, but which would not be really seen in views given, are indicated by fine dotted distinct black lines in India ink. Section lines in cast iron are black; in wrought iron, blue; in steel a darker blue and closer together; in brass, of chrome yellow.

These lines are all exemplified in the plate of the spur wheel, but can be distinguished from each other in practical draughting by using different colored inks in the way suggested and usually adopted. Attention is called to the necessity and utility of centre and radii lines. Work from centre lines is the mechanic's and the draughtsman's rule. So useful are they that, although not always required, it is a good plan to draw two centre lines at right angles with each other through every circle in the drawing. They are "good to measure from," and if the drawing is to be traced it enables the copyist to find the centres at once without *feeling* or guessing for them.

Delineation of a Bevel Gear Wheel.

Spur-gear wheels are only capable of transmitting motion between shafts which are parallel, but when shafts are at an angle with each other, the wheels require to be made conical instead of cylindrical, and are termed bevel-gear wheels. Spur-gearing, then, refers to all cases where the shafts are parallel, and where the pitch lines roll together on the principle of cylindrical rollers with fixed axis rotating together; bevel gearing refers to cases where the shafts are placed angularly one with another, and where the wheels require to be made conical, the pitch lines rolling together on the principle of two cones with fixed axes rotating by the friction of contact. We have often heard the question asked, and quite recently, "What is a mitre wheel?" And we will tell the student right here that Fig. 61 gives views of such a wheel. When there is a vertical shaft to be driven by a horizontal one, or *vice versa*, and both are to have the same speed, the wheels of course must be the same size, and in *this case only* will the angle of conical contact be 45° or half a right angle. In short, a mitre wheel is one having teeth constructed to work at an angle of 45°, and it will engage or gear only with

another wheel of its own size and having the same angle. Hence, when we speak of wheels as being "mitres," we mean that the wheels are of the same diameter and of the same angle, viz., 45°. If a vertical shaft has a bevel-gear wheel 12 inches in diameter, and this gives motion to a horizontal shaft having a wheel 12½ inches in diameter, the wheels will not be "mitres," neither will the angle be 45°.

Fig. 62 shows a section, a half-rear elevation, a half-front elevation, a plan, and a section of one of the arms of a mitre-wheel. Commencing with the section on the left of the plate, we remark that this is the first view to be drawn; it is the most important and the one most generally given in practical draughting, as it shows the angle and breadth, and certain proportions of the tooth. The teeth of bevel-gear wheels are made of wood or metal, similarly to spur-wheel teeth, and their geometrical forms are determined on the same principles. Therefore the proportions for teeth already given apply to the class of wheels we are now explaining. The first lines to be drawn in getting a *section of a bevel-gear wheel*, are the horizontal, centre, and vertical pitch lines shown extended beyond the figures. Upon the latter set off the diameter of the wheel, and (if the wheel is a mitre) draw lines through the diameter points at 45°, as shown by the dotted lines in the section view. From the point of intersection set off so much above for the top part and so much below for the bottom part of the tooth whatever proportions may be decided upon; this may be done at both extremities of the diameter line, although not always required, as unless the *other views* are to be given, there is nothing gained by repetition. The top and bottom points of the tooth being fixed, draw lines towards right-hand point of intersection on the centre line. [NOTE: This line gives the angle of the face of the tooth and of the face of the whole wheel, and is neither an angle of 45°, nor of course

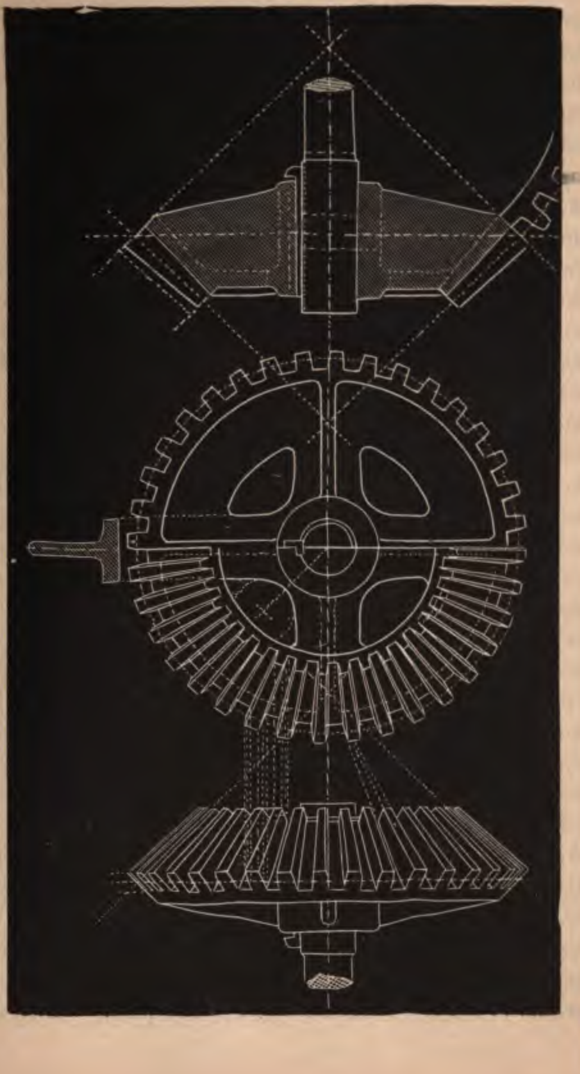


Fig. 62.

parallel with the *working* dotted line.] We are explicit here, because students are apt to make a mistake, and draw the top and bottom lines of the tooth parallel with the working or theoretical line at 45°. All lines of the tooth must be drawn towards the points of intersection on the centre line, or at right angles, as clearly shown in the plate. All the teeth converge in one point. The thickness of the rim is next set off below the bottom of the tooth, and a line drawn to the point of convergence will give the bottom of the rim (which is thinner) on the inside of the wheel. The section of arms, diameter of shaft, key, length and diameter of hub, are given in this view; their proportions depend upon circumstances—what duty the wheels have to perform. To get the true form of the top of the tooth and rim, four circles are struck from the extreme left centre, with radii determined by points of tooth and rim in section. The next views to be obtained are the half-front and half-rear elevations. The way in which we can make the drawing of these views most easily understood is to state the explanation in a few simple directions. Draw circles corresponding in diameter to all the points and lines already found in the section view; one for shaft, another for the hub, another for the extreme diameter, another for the pitch circle, etc., not forgetting that the last is the most important, just as in spur-gear wheels. Now, upon the pitch circle, space off the teeth and treat it as you would a spur wheel, as shown in the half-rear elevation on the left of the view. Then draw all lines of the face towards the main centre of the wheel. Again we remind the student that the form of the tooth is obtained and drawn in a similar way to that used for spur gearing. The plan view is obtained by repeating the section view *first*, and then drawing vertical lines from the exterior points of the tooth and rim. Lines are next projected from *points* in the half-front elevation to the plan. So many lines

may give the student an idea that there is much intricacy in the matter. We assure him it is a matter only of common sense. Let him procure a small bevel wheel, study it, and then remember that the points in one view give him the points in the other view. For instance, the pitch circle is the same in the half-rear and the half-front elevations; on this circle the centres of the teeth are spaced off, the thickness of the tooth shown, but the top and bottom circles of the teeth must agree with the top and bottom points of the tooth in section. The dotted lines show clearly the relative and corresponding points in the different views; a study of these will help the student far more than wading through a long verbal explanation. Draw the section view first; from this get the half-rear and front elevations; then draw out the section outline again; draw vertical lines from points thus obtained, and on these lines project the points from the ones on the circles—points of teeth in elevation on to vertical line of largest diameter in plan; points on pitch circle in elevation to pitch line in plan; bottom of teeth in elevation to bottom of teeth in plan, etc.

In leaving the subject of gearing, we must say to the student there are many valuable works on the subject, and much has been and is being written on it. We have only attempted here to instruct him in elementary principles, from which he will readily see that the subject deserves his further study and research. There are many kinds of wheels, and many combinations of them, involving nice calculations, which the limits of this book only allow allusion to. Master spur gearing thoroughly, and afterwards bevel gearing will not be found so difficult to draw as the numerous lines would seem to indicate.

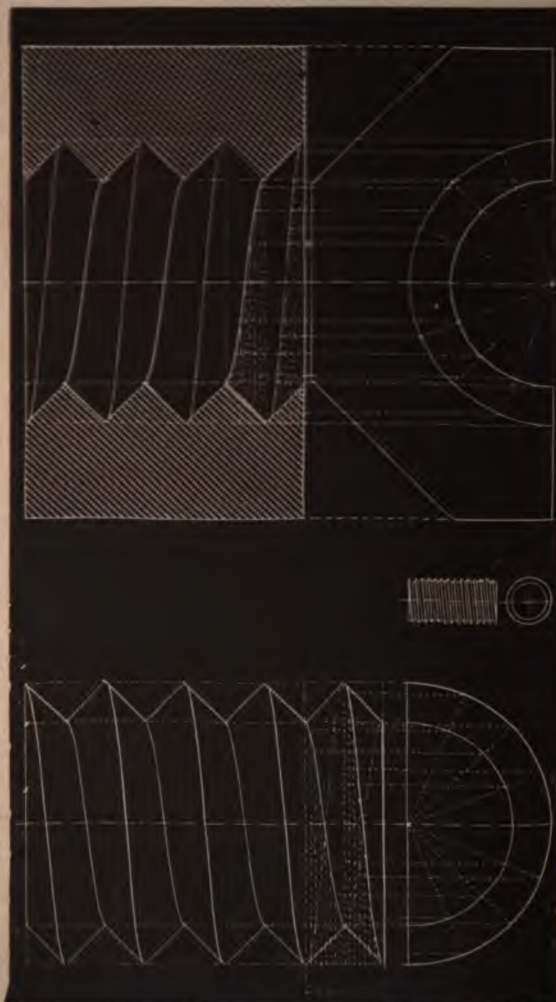


Fig. 63.

The Delineation of Screws.

Screws are used in machinery and in mechanical combinations, either for securing various pieces to each other, so as to produce contact pressure, or for communicating motion. They are constructed in various forms for an infinite variety of purposes. Those used in wood work by carpenters and joiners, differ materially from those employed in metals, but all have what is termed a "thread," that gives the holding grip. This thread consists of a spiral ridge or a groove, winding round a cylindrical or conical body. A simple illustration is afforded by taking a cord or string and winding it spirally round a roller. It will then be noticed that the path of the string is not in straight lines, but in a continuous advancing curve—a point traveling round a cylinder, having at the same time a motion in the direction of the length of the cylinder, and this longitudinal motion bearing some regular prescribed proportion to the circular or angular motion. This curve is called a *cylindrical helix.*

Screws are of two kinds: convex, also called external or male, and concave, also called internal or female. A screw that has a triangular thread is commonly known as a **V**-threaded screw in distinction from one having a square, round, or other shaped thread. Fig. 63 represents a **V**-thread screw; the drawing to the left, is the external, and the one to the right the internal. When a hole is drilled and tapped in a piece of metal, an internal or female thread is formed, and in the grooves of this the external projecting thread, or male screw, must accurately fit. Every bolt and nut observable in machinery is an illustration of this. And just here we will remind the student that in drawing machinery, and buildings, he will find many different forms of screws, bolts and nuts. Some with square and round heads, others

with hexagonal heads and nuts. These heads are distinguished by certain technical terms as T, square, hexagon, capstan, cheese, snap, oval, conical, pan, countersunk, plowheads, and so on. There are also set, coach, machine, wood screws, etc., and among bolts he will find stove, machine, collar, cotter, carriage, and tire bolts. Of some of these we give illustrations in plates 64 and 65. But what requires the student's attention most, is the threads of these bolts and screws, of which there are likewise quite a variety, as the **V.**, English standard, U. S. standard, bastard, ratchet, square, and wood screw. The drawing of these requires a knowledge of rules and principles, with which all practical draughtsmen are more or less familiar. Such eminent engineers and machinists as Sir Joseph Whitworth, of England, William Sellers, of Philadelphia, Pratt & Whitney Co., of Hartford, and Brown & Sharpe, of Providence, have given the subject of screw threads much examination and attention, and have demonstrated wonderful mechanical closeness and perfection in screw-cutting tools. They have detetermined in their respective judgements which are the best working and strongest angles of screw threads, the number of threads in one inch for certain diameters, and the best form of threads for certain purposes. Therefore, the subject is an important one, about which, like gearing, a great deal has been printed, and some of which in condensed form, is accessible for the student's examination in Haswell's, Trautwine's, Nystrom's, and Roper's engineers' pocket books. In these the student will find the best proportions for bolts and nuts, and the number of threads per inch for certain diameters.

On account of the great number of screws, bolts and nuts, that are required in the construction of machinery, and which it is necessary to show in drawing it, there is no occasion to *represent* threads strictly accurate, but straight lines are usu-

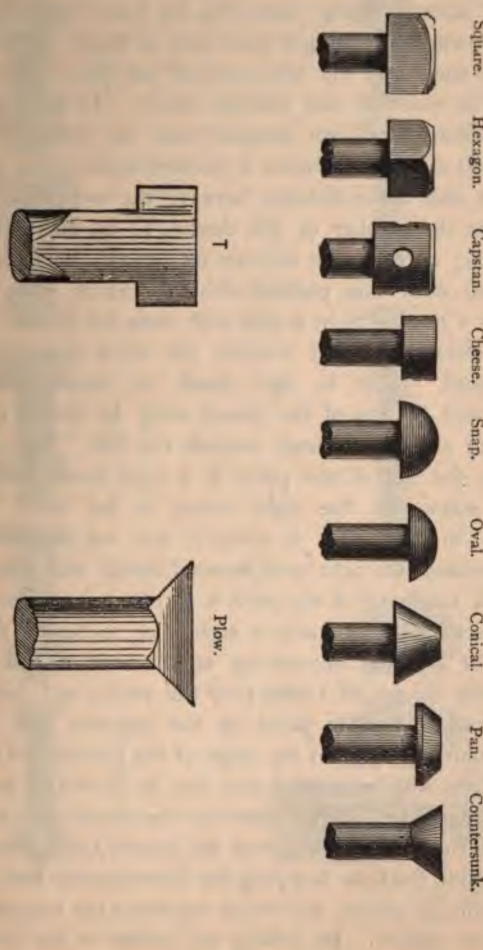

HEADS
Square.
Hexagon.
Capstan.
Cheese.
Snap.
Oval.
Conical.
Pan.
Countersunk.
T
Plow.

Fig. 64.

ally substituted for curves, unless the screw is of considerable diameter, and the accuracy and style of the drawing require it. The accompanying plate, Fig. 63, has a small **V**-thread screw, drawn with straight lines, and a larger one with diagrams, to show how the true curve of the thread is obtained for both an external and internal screw. To draw a screw in the ordinary way with straight lines, the first thing to be determined after the diameter is decided upon, is the pitch of the screw, that is the distance between the two points of the threads, or the number of the threads to an inch. Draw a centre line; on each side of it set off half the diameter of the screw, and draw lines parallel with the centre line; at one end draw a line at right angles with these for the end of the screw. Determine next whether the screw is to be right or left hand. If it is right hand, the lines representing the top and bottom of the thread must be drawn towards the right; and if left hand, towards the left. The external screw on the left of the plate is a right hand thread, the internal screw on the right shows a left hand thread although in this case it really is not nor could be one, but is a *section* of a right hand internal thread which naturally shows left handed. If the pitch is 1/8 of an inch, the spaces must be set off on one side in eighths of inches for the outside of the thread commencing at the end of the screw; *before doing this* set off 1-16th (half the pitch), and then draw a line from the bottom point, on the opposite side, to the 1-16th point. This gives the angle of the thread, and all successive lines will be parallel with this, as shown in the small screw in the plate. Then determine the depth of the thread and draw two lines parallel with the centre line; these serve only as guide lines for stopping the intermediate lines drawn between the 1/8 spaces, and which represent the bottom angle lines of the thread. By joining the points of the long and

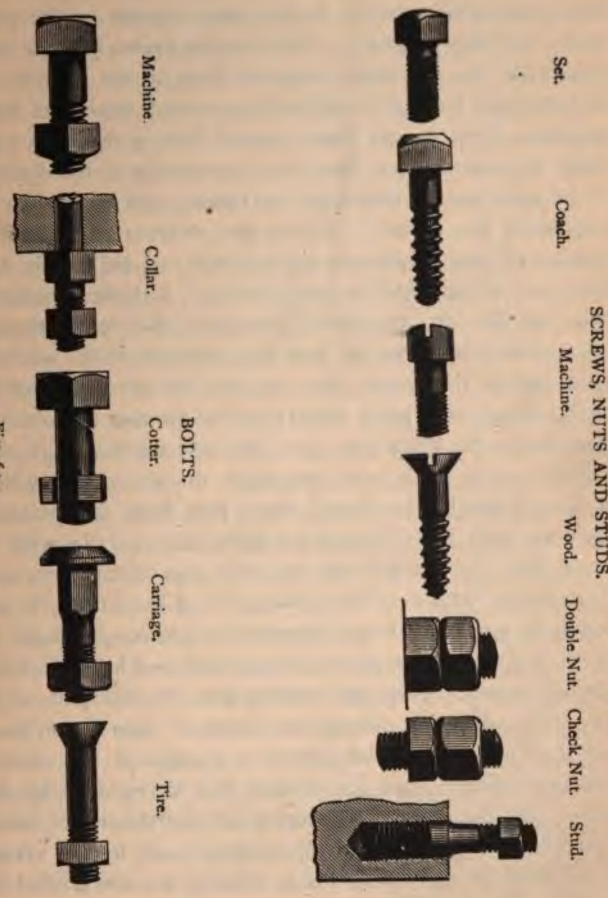

SCREWS, NUTS AND STUDS.
Set.
Coach.
Machine.
Wood.
Double Nut.
Check Nut.
Stud.
BOLTS.
Machine.
Collar.
Cotter.
Carriage.
Tire.

Fig. 65.

shorter lines with short angular lines, the thread is completed. A section of the thread gives an isosceles triangle. Now all this is more fully shown in the larger figures of the plate, where the helix is given. The screw is drawn just the same way, with the difference that the lines of the outside and bottom angle lines of the thread are curved, instead of being straight. Now to get these curved lines is simple enough. Draw two centre lines: describe a semicircle of the diameter of the screw for the outside of the thread, and another for the bottom of the thread. Divide the outer circle into any number of equal parts, say eight, which can be readily done with the triangle having 90° and 45°, without spacing off with the dividers, and draw lines from the centre through both semicircles. Set off half the diameter of the screw on each side of the centre line; on the left side space off the pitch; divide this pitch into twice the number of parts that there are in the semicircle. In this case we have eight, and half the pitch must have also eight divisions. Draw these lines as shown by the dotted ones; then from the points in the outer and inner semicircles draw lines parallel with the centre line, and intersecting the short ones already drawn at right angles with it. Then the path of the curves is from corner to corner in short diagonal lines, *passing through the points of intersection* made by the vertical and horizontal lines of the diagram. Note particularly here, that the path of the top of the thread is through the points of intersection made only by the lines extended from the points in the outer or largest semicircle, and the dotted lines at right angles with them; but the path of the bottom of the thread, or shorter curve, is through points of intersection made by the vertical lines drawn from the smaller or interior semicircle, and the dotted lines at right angles with them. In other words, all the lines drawn from the larger semicircle belong to the

longer curve, or outside of thread, and the lines drawn from the smaller or inner semicircle belong to the shorter curve or bottom of the thread. The curves of the interior or female screw, shown in the section of a nut on the right of the plate, are drawn in precisely the same way as already described, only that the curve is towards the left instead of towards the right. In looking at the section of a right-hand thread in a nut, the curves will be left-hand, which a little thought and observation will soon make the reason of this quite clear.

Fig. 66 represents four V-threaded iron screws with different shaped heads. As these are drawn full size and shaded, the student will get a clear idea of how bolts, nuts, and screws are represented in the usual way. Generally the heads only are shaded; the thread being inserted in the metal is, of course, hid from view and represented by dotted lines, unless the view is a sectional one, when the thread may be represented as shown. It is seldom, however, that the shading is put in, for the reasons that it is not absolutely necessary, and that while it improves the look of a drawing and is in itself strictly correct, too much time would be consumed in putting it in. The matter of line shading is optional with the practical draughtsman. If the drawing is to be made very plain, very intelligible, and to be finished artistically and well, then shading by lines or by the brush in India ink may be introduced; but if you commence to shade with lines, shade throughout with lines; if you commence to shade with India ink and colors, shade throughout with the brush. *Long practice, a steady hand, a correct eye, patience, and perseverance* are all necessary for the attainment of artistic shading—an art which bears no slighting or imperfections. Therefore, like painting in oil colors, you will have to make many drawings and pictures before you will make one artistically correct and pleasing. Your attention should be devoted chiefly to the making

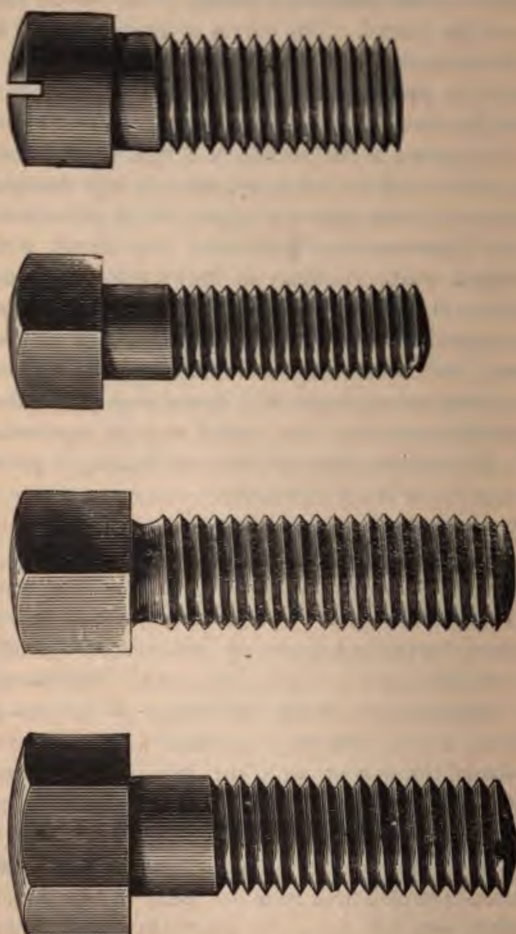

Hexago.i Cap Screw.
ron Set Screw.
Square Head Cap Screw.
Round Head Cap Screw.

Fig. 66.

of construction drawings, which are frequently of great value and usefulness. A picture of machinery beautifully lined and shaded is a work of art, and to mechanical eyes as pleasing as a highly finished oil painting; but such pictures are costly; photography has taken the field, and they are seldom made. Still, machine pictures are a fascinating study. The author has spent months at a time over India ink pictures, and the work never became irksome. Study tinting and shading under an experienced draughtsman.

Drawing a Square-Thread Screw.

Set off a diagram similar to the one for a V-thread. Divide half the pitch into the same number of parts as the semicircle, or the whole pitch into twice the number of parts as there are in the semicircle. The lines of the threads are drawn through the points made by the intersection of the projected vertical lines from the larger semicircle, and horizontal lines at right angles with them. The smaller curves are drawn through the points made by the intersection of vertical lines projected from the *smaller* circle, and the horizontal lines at right angles. Note: The portion of the thread seen at the back is drawn just the same way as the longer curve, but its path is towards the left in a right-hand thread screw, and only a portion of it can be seen at each side. Note, again, the pitch of a square-thread screw is known in the same way as a V-thread, viz., the distance from the centre of one thread to the centre of the other. The width of the thread and space between the threads in screws is the same; the depth of the thread is commonly made the same as the width of the thread. Comparing Fig. 67, showing the diagrams and illustrations of a square-thread screw, with that of the V-thread, you will find that there is a resemblance between the two. The principle is the same in both cases, only the one is a V and the other a square thread.

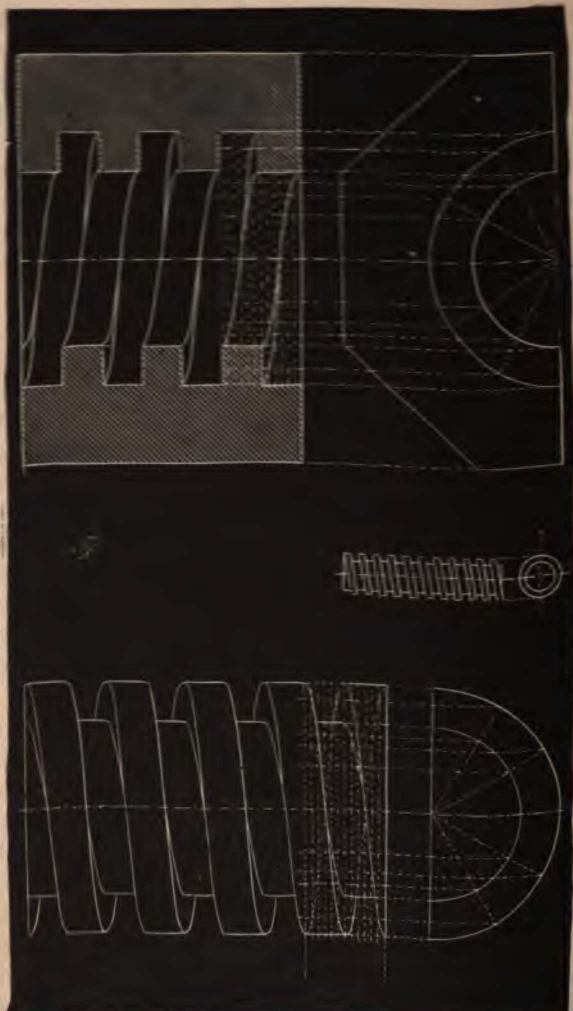


Fig. 67.

Note, again, that in the section of the nut the curves go up towards the left because, as before, you are looking at the back of the screw, which is a right-hand one.

If the student should experience any difficulty in mastering these diagrams and curves, let him consult a good draughtsman or teacher, who, by a few strokes of a lead pencil, can easily make them plain. But the drawings and diagrams in the given figures are *just right* on a small scale, and if the student will *copy them twice* or *three times* the size, they will become easier to understand. Unless the screws drawn out by him coincide in every particular with those shown here for his guidance, he may be sure he is in error somewhere.

Copying Drawings.

There are several methods for reproducing mechanical and architectural drawings, the easiest being to trace them. Thin tracing paper, or tracing vellum cloth, both being transparent, are used for this purpose. The former can be obtained in sheets and rolls; the latter in rolls only. When a copy of a drawing is intended for workmen, or when it is likely to receive much handling, the vellum cloth is preferable, as it is not easily torn. Copies are made on tracing paper when they are to be mailed or mounted on boards, in a manner we shall explain. The vellum cloth is put over the drawing, and on being pulled moderately tight is secured to the drawing-board by thumb tacks. It does not admit of being dampened and stretched; it is pinned down over the drawing without any preparation.

Tracing paper may be manipulated in a different manner. Lay the drawing to be copied squarely on the drawing-board, and secure it by thumb tacks. Take a sheet of tracing paper, a little larger than the drawing. By means of mucilage and brush, gum down the edges of the tracing

paper to the drawing board, not to the drawing to be copied; do not pull the sheet tight. After a few minutes take a damp sponge and rub it all over the tracing paper except at the gummed edges. Leave it to dry. In a few minutes the paper will have contracted, and present a beautiful smooth surface, resembling a child's transparent slate. In this condition it is very convenient for drawing upon and coloring. Note, that unlike the process of mounting drawing-paper, which is moistened *before* being gummed down, tracing paper is moistened *after* it has been gummed to the board *over* the drawing. When the copy is completed, it can be removed by cutting within the gummed edges, and the gummed strips adhering to the board are easily removed by sponge and water. These paper tracings are very delicate affairs, and do not admit of much usage. They have to be "used right side up with care." But if the tracings are for construction purposes they should have the dimensions figured on them, and then they may be mounted on boards in the following manner. Get a smooth pine board, half an inch thick, with battens on the back, a little larger than the tracing. Give this board two coats of moderately thin shellac varnish, white or brown; the former is preferable for this purpose. Turn the tracing over and give the back a coat of same varnish. Before it dries (it dries quickly) lay it as smoothly as possible upon the board. You will find that the air underneath it must be at once expelled, and these air blisters are got rid of by smoothing them out with a smooth cloth or silk pad, stroking out from the centre to the sides. The operation requires care and some skill in order to secure a smooth unwrinkled surface, but when the varnish has dried and the tracing has contracted, the drawing looks as if drawn on the board. It is a permanent fixture. When pulled tight and it is dry, a coat of *shellac varnish* may be applied, which renders the lines indelible.

This system of taking copies from drawings and mounting the tracings on boards, in the manner described, is practiced in a number of the largest machine works in this and other countries. It allows the original paper drawings to be retained, filed, and kept in good condition in the drawing office, and furnishes workmen with drawings that cannot be torn or mutilated, provided proper care is taken of them. White shellac varnish is easily prepared by dissolving the shellac in alcohol. When making tracings, follow the system adopted as the correct one by all draughtsmen, by inking in first the small circles and curves, then the larger ones, then all the horizontal lines, beginning at the top of the drawing and working downwards, then all the vertical lines commencing at the left and moving back to the right, then the oblique lines; last of all the centre lines in red (carmine), and dimension and reference lines in blue (Prussian blue) or *vice versa*. The figuring and lettering should be always done with India ink, thoroughly black. The reason why irregular curves and arcs of circles are inked in first is, that it is easier to draw a straight line up to a curve than to take a curve up to a straight line. If tracings are required to be tinted or shaded, the color may be applied before the tracing is cut off, or what is more usual, the color may be applied on the back of the tracing; then there is no liabilitiy to wash out the lines. This plan of coloring on the back is adopted for both vellum and paper tracings.

Construction Drawings.

An ex ellent way of making construction drawings, adopted in some English and American works, is to have pine boards squared up, planed over and sand-papered, then to wash the surface over with size. A little melted glue in a pint of warm water is generally sufficient for a board of moderate size.

When the size has dried, rub over gently with fine sand-paper. The board is ready to be drawn on, and may be treated as if paper, by first penciling, then inking in and shading up with ink lines. Shading is more quickly and very effectively done by using a moderately soft pencil. The curved surfaces are well brought out by free-hand shading. Dimensions can be written on in figures; centre and dimension lines put in blue and red, etc. When completed, a coat or two of brown shellac varnish, such as is used by pattern makers, may be applied, and a permanent, plain drawing is obtained, from which tracings, if required, can be made in the same manner as from paper. Workmen like such drawings to "work by." When dirty they can be washed. They cannot be torn, and they last a long time. Where there is a number of machines of the same kind to be made, or a quantity of articles of one pattern to be constructed, this is a very desirable plan, and useful to architects and engineers. When the drawings are done with, the boards can be planed over, resized, and become ready for further use. This is also an excellent way for furnishing drawings intended for forges and blacksmiths. The usual way of furnishing drawings is to make them on a Double Elephant, or other size drawing paper; to finish them with shade lines, and colored or lined sections, and figure all the dimensions so accurately and so distinctly that the drawing can be read by pattern makers, machinists, and all interested in the construction of the machinery. As the sheets are completed, copies may be taken, filed, and kept for reference. Architects, masons, engineers, and machinists have all their own ideas and plans regarding furnishing drawings, but a thorough knowledge of the rules and instructions here given will enable the student to adapt himself readily to any system that may be considered best for particular workshops and special purposes.